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A FORTRAN V PROGRAM FOR PREDICTING THE DYNAMIC RESPONSE OF THE APOLLO COMMAND MODULE TO EARTH IMPACT

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16. Abstract

A FORTRAN V digital-computer program, capable of determining the nonlinear motion of two six-degree-of-freedom rigid bodies connected by shock struts and subjected to ground impact, is presented in this report. A sample problem is included to provide a correlation between computer results and actual test results.

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CONTENTS

TABLES

FIGURES

Figure | Page

A FORTRAN V PROGRAM FOR PREDICTING THE DYNAMIC RESPONSE OF THE APOLLO COMMAND MODULE TO EARTH IMPACT

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SUMMARY

A digital-computer program, capable of determining the nonlinear motion (in a gravity field) of two six-degree-of-freedom rigid bodies connected by shock struts and subjected to ground impact, is presented in this report. A sample problem is included to provide a correlation between computer results and actual test results. All axis systems and equations used in the digital-computer program and a procedure for using the computer program are also presented in this report.

INTRODUCTION

A mathematical approach for determining the dynamic response of a falling body to impact with a soil surface is presented in this report. Although the approach presented in this report is specifically applied to the Apollo command module structure and crew couch, the approach can readily be adapted to a wider range of similar dynamic problems associated with the impact of falling bodies.

A successful Apollo manned mission terminates with the command module (CM) impacting on water. If the mission should be aborted, however, a land impact could occur, and this impact would result in severe loading on the capsule-couch system. Under these circumstances, couch acceleration must be kept within human exposure limits, and couch-strut stroking must restrict couch excursion to a specified acceptable clearance envelope within the CM. To determine analytically the dynamic response of the capsule-couch system to earth impact, a 12-degree-of-freedom mathematical model was formulated, and a digital-computer program was written to carry out the computations.

The three types of capsule-couch interconnecting struts that may be handled by the computer program are linear spring shocks with damping proportional to the square of the velocity, honeycomb shocks with Coulomb damping, and cyclic-deformation struts with structural damping. The computer program contains four independent empirical soil-force equations with nine input constants, which can be altered to correlate with different soil types. The computer-program input also permits the user to specify the location of a three-axis accelerometer anywhere on the crew couch. Appendix A gives the computer-program listing. Appendix B provides data on the general input and output of the program.

SYMBOLS

A1	number to control the switch from truncation error to relative truncation error in the variable-step Adams-Moulton integration routine (order 10^{-3})
A2	upper bound for the single-step error in the variable-step Adams-Moulton integration routine (order 10^{-5})
A3	lower bound for the single-step error in the variable-step Adams-Moulton integration routine ($A3 \geq A2/55$)
A4	lower bound for the step size in the variable-step Adams-Moulton integration routine ($A4 > 0.0$)
A5	upper bound for the step size in the variable-step Adams-Moulton integration routine
A7	factor for reducing the step size in the variable-step Adams-Moulton integration routine
$ACCEL_{2,i,2}$, $ACCEL_{2,j,2}$, $ACCEL_{2,k,2}$	components (parallel to the i_2-, j_2-, and k_2-axes, respectively) of the relative-displacement vector from $c.g._2$ to the accelerometer mounted on body 2, in.
AC(n)	elemental areas associated with points $S_{1,n}$ ($n = 1, 2, \ldots, NSK$), in^2
AKC	soil coefficient for the dynamic vertical force due to the velocity of the structure moving vertically into the soil (for use after soil-wedge formation)
AKNT	slope of the dynamic vertical soil-force loading line prior to soil-wedge formation, lb/in.
AKP_n	slope of the honeycomb $SHOCK_n$ compression unloading line ($n = N_{SS} + 2, \ldots, N + 1$), lb/in.
AKPS	slope of the honeycomb couch-bumper unloading line, lb/in.

AKT_n — slope of the honeycomb $SHOCK_n$ tension unloading line ($n = N_{SS} + 2, \ldots, N + 1$), lb/in.

AMU — friction coefficient between the structure and the soil

AR_o — origin of the Apollo reference-system coordinates

AREA1 — area associated with any given point on edge ring 1, in^2

AREA2 — area associated with any given point on edge ring 2, in^2

AREA3 — area associated with any given point on edge ring 3, in^2

ARS1 — relative-displacement vector from AR_o to point RS1 along the X-axis, in.

ARS2 — relative-displacement vector from AR_o to point RS2 along the X-axis, in.

ARS3 — relative-displacement vector from AR_o to point RS3 along the X-axis, in.

BKC1S — slope of the honeycomb couch-bumper loading line, lb/in.

BOFF — slope of the static vertical soil-force unloading line, lb/in.

C_{ST} — structural damping coefficient for the cyclic-deformation shock struts (when they are used), lb-sec/in.

CD_n — equivalent fluid-damping coefficient for spring $SHOCK_n$ ($n = 2, \ldots, N_{SS} + 1$), $lb\text{-}sec^2/in^2$

CDO — soil drag coefficient for the horizontal drag force due to the horizontal velocity of the structure moving through the soil

CGO — soil drag coefficient for the horizontal drag force due to vertical penetration of the structure into the soil

CK_n — spring constant of spring $SHOCK_n$ ($n = 2, \ldots, N_{SS} + 1$), lb/in.

CL_n — equilibrium position of $SHOCK_n$ ($n = 2, \ldots, N + 1$), in.

$c.g._n$ — center of gravity of body n ($n = 1, 2$)

$c.g._{x,n}$, $c.g._{y,n}$, $c.g._{z,n}$	components about the i_n-, j_n-, and k_n-axes, respectively, of the total torque acting through $c.g._n$ $(n = 1, 2)$, in-lb
DENSTY	soil density, lb/in^3
DR1	compression stroke required to reach the constant-crush level of a point on edge ring 1, in.
DR2	compression stroke required to reach the constant-crush level of a point on edge ring 2, in.
DR3	compression stroke required to reach the constant-crush level of a point on edge ring 3, in.
E	modulus of elasticity for the heat-shield facing material, lb/in^2
$EL1C_n$	strut compression stroke required to reach the first constant-crush level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.
EL1CS	couch-bumper compression stroke required to reach the constant-crush level, in.
$EL1T_n$	honeycomb or cyclic-deformation strut tension stroke required to reach the first constant-load level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.
$EL2C_n$	strut compression stroke required to reach the end of the first constant-crush level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.
$EL2T_n$	strut tension stroke required to reach the end of the first constant-crush level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.
$EL3C_n$	strut compression stroke required to reach the second constant-crush level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.
$EL3T_n$	strut tension stroke required to reach the second constant-crush level of honeycomb $SHOCK_n$ $(n = N_{SS} + 2, \ldots, N + 1)$, in.

$F_{B,i,n}$, $F_{B,j,n}$, $F_{B,k,n}$	components of couch-bumper force acting on body n along the i_n-, j_n-, and k_n-axes (n = 1, 2), respectively, lb
$F_{H,MAX}$	maximum force in the honeycomb shock struts, lb
$F_{S,MAX}$	maximum force in the spring shock struts, lb
$F_{x,1}C_n$, $F_{y,1}C_n$, $F_{z,1}C_n$	components of force due to $SHOCK_n$ (n = 2, ..., N + 1) acting on body 1 parallel to the i_1-, j_1-, and k_1-axes, respectively, lb
$F_{x,2}C_n$, $F_{y,2}C_n$, $F_{z,2}C_n$	components of force due to $SHOCK_n$ (n = 2, ..., N + 1) acting on body 2 parallel to the i_2-, j_2-, and k_2-axes, respectively, lb
FA	internal soil-friction angle, rad
FD_n	total damping force in $SHOCK_n$ (n = 2, ..., N + 1), lb
FD(n)	total horizontal soil force acting at point $S_{1,n}$ (n = 1, 2, ..., NSK), lb
FEC13M	left-side couch-bumper compressive force at the start of a computer run, lb
FEC13P	right-side couch-bumper compressive force at the start of a computer run, lb
$FEC13S_n$	strut compressive force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2$, ..., N + 1) at the start of a computer run, lb
$FEM13S_n$	strut tensile force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2$, ..., N + 1) at the start of a computer run, lb
$FFNSN_n$	strut friction force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2$, ..., N + 1) when the piston moves away from the equilibrium position in the compressive end of the cylinder, lb

$FFNSP_n$ — strut friction force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$) when the piston moves toward the equilibrium position from the compressive end of the cylinder, lb

$FFPSN_n$ — strut friction force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$) when the piston moves toward the equilibrium position from the tensile end of the cylinder, lb

$FFPSP_n$ — strut friction force in honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$) when the piston moves away from the equilibrium position in the tensile end of the cylinder, lb

$FG_{i,n}, FG_{j,n}, FG_{k,n}$ — components of the gravity force acting on body n along the i_n-, j_n-, and k_n-axes ($n = 1, 2$), respectively, lb

FHD(n) — dynamic horizontal soil force acting at point $S_{1,n}$ ($n = 1, 2, \ldots, NSK$), lb

FHS(n) — static horizontal soil force acting at point $S_{1,n}$ ($n = 1, 2, \ldots, NSK$), lb

FK_n — total nondamping force in $SHOCK_n$ ($n = 2, \ldots, N + 1$), lb

FR1 — constant-crush level of a point on edge ring 1, lb

FR2 — constant-crush level of a point on edge ring 2, lb

FR3 — constant-crush level of a point on edge ring 3, lb

$FS_{i,1}, FS_{j,1}, FS_{k,1}$ — components of the total soil force acting on body 1 along the i_1-, j_1-, and k_1-axes, respectively, lb

$FS_{i,1,n}, FS_{j,1,n}, FS_{k,1,n}$ — components of the soil force acting on body 1 at point $S_{1,n}$ ($n = 1, 2, \ldots, NSK$) along the i_1-, j_1-, and k_1-axes, respectively, lb

FSN(n) — component of force FSR(n) normal to a tangent plane at point $S_{1,n}$ (or at point $S_{1,RS1,n}$) ($n = 1, 2, \ldots, NSK$), lb

FSR(n)	total soil force acting at point $S_{1,n}$ ($\lvert FSR(n)\rvert = \sqrt{FD(n)^2 + FVT(n)^2}$) (n = 1, 2, ..., NSK), lb
FVD(n)	dynamic vertical soil force acting at point $S_{1,n}$ (n = 1, 2, ..., NSK), lb
FVS(n)	static vertical soil force acting at point $S_{1,n}$ (n = 1, 2, ..., NSK), lb
FVT(n)	total vertical soil force acting at point $S_{1,n}$ (n = 1, 2, ..., NSK), lb
G	acceleration of gravity, in/sec^2
$G_{B,i,n}$, $G_{B,j,n}$, $G_{B,k,n}$	components about the i_n-, j_n-, and k_n-axes, respectively, of the torque acting through c.g.$_n$ (n = 1, 2) due to the couch bumper, in-lb
$G_{\overline{\overline{X}}}$, $G_{\overline{\overline{Y}}}$, $G_{\overline{\overline{Z}}}$	components of the acceleration of gravity along the $\overline{\overline{X}}$-, $\overline{\overline{Y}}$-, and $\overline{\overline{Z}}$-axes, respectively, in/sec^2
$G_{x,1,n}$, $G_{y,1,n}$, $G_{z,1,n}$	components about the i_1-, j_1-, and k_1-axes, respectively, of the torque acting through c.g.$_1$ due to SHOCK$_n$ (n = 2, 3, ..., N + 1), in-lb
$G_{x,2,n}$, $G_{y,2,n}$, $G_{z,2,n}$	components about the i_2-, j_2-, and k_2-axes, respectively, of the torque acting through c.g.$_2$ due to SHOCK$_n$ (n = 2, 3, ..., N + 1), in-lb
GCØNST	soil coefficient for the static vertical force due to vertical penetration of the structure into the soil
GPOWER	power to which the vertical penetration of the structure into the soil is raised in the static vertical-force soil equation
$GS_{i,1}$, $GS_{j,1}$, $GS_{k,1}$	components about the i_1-, j_1-, and k_1-axes, respectively, of the torque acting through c.g.$_1$ due to the total soil force, in-lb
$GS_{i,1,n}$, $GS_{j,1,n}$, $GS_{k,1,n}$	components about the i_1-, j_1-, and k_1-axes, respectively, of the torque acting through c.g.$_1$ due to the soil forces acting at point $S_{1,n}$ (n = 1, 2, ..., NSK), in-lb

HEATB	component of the relative-displacement vector from AR_o to the edge of the capsule along the Z-axis, in.
hh	average heat-shield thickness, in.
$I_{i',n}, I_{j',n}, I_{k',n}$	body n moments of inertia about the i'_n-, j'_n-, and k'_n-axes (n = 1, 2), respectively, $lb\text{-}sec^2/in.$
i_n, j_n, k_n	arbitrarily oriented orthogonal body axes originating at $c.g._n$ (n = 1, 2) (j_1-axis must be parallel to X-axis)
i'_n, j'_n, k'_n	principal inertial axes for body n (n = 1, 2)
$\bar{i}_n, \bar{j}_n, \bar{k}_n$	unit vectors directed parallel to and in the positive direction of the i_n-, j_n-, and k_n-axes (n = 1, 2), respectively
$\bar{i}'_n, \bar{j}'_n, \bar{k}'_n$	unit vectors directed parallel to and in the positive direction of the i'_n-, j'_n-, and k'_n-axes (n = 1, 2), respectively
LBC	length of the radius r_{LBC} which defines a ring containing the bolt-circle points (figs. 10 and B-3)
$[\ell_n]$	matrix of the direction cosines for transforming vector components from the principal body axes of body n (n = 1, 2) to the arbitrarily oriented axes of the same body
M_n	mass of body n (n = 1, 2), $lb\text{-}sec^2/in.$
N	total number of spring-damper and honeycomb struts (not including couch lateral bumpers)
$N_{H, MAX}$	identifying number of the honeycomb strut which has the maximum force
$N_{S, H, MAX}$	identifying number of the honeycomb strut which has the maximum stroke
$N_{S, MAX}$	identifying number of the spring strut which has the maximum force
N_{SS}	number of spring struts

$N_{S, S, MAX}$	identifying number of the spring strut which has the maximum stroke
NBC	number of points on the heat-shield bolt circle
NOOR	number of rings of points on the heat shield (includes the bolt-circle ring)
NOTHT	number of radial lines of points on the heat shield
NPHS	heat-shield point corresponding to YHSM
NPR1	ring 1 point corresponding to YR1M
NPR2	ring 2 point corresponding to YR2M
NPR3	ring 3 point corresponding to YR3M
NSK	number of points of the heat shield which are capable of deflecting
P	point of intersection of plane R and the heat-shield rim in the direction of the vehicle velocity vector
$P_{1, n}, P_{2, n}$	points on bodies 1 and 2, respectively, for which the relative-displacement vectors are determined ($n = 1, 2, \ldots, N + 1$) (also the shock attachment points for $n = 2, 3, \ldots, N + 1$)
$\overline{P_{1, n}P_{2, n}}$	magnitude of the relative-displacement vector from point $P_{1, n}$ to point $P_{2, n}$ ($n = 1, 2, \ldots, N + 1$), in.
P_{2+L}, P_{2-L}	tips of the right-side and left-side couch lateral bumpers, respectively.
PENETRATION(1)	depth of penetration of point $S_{1, 1}$ into the soil, measured parallel to the Y-axis
R	plane defined in figure B-1
$R_{S, n}$	position vector from $c.g._1$ to point $S_{1, n}$ (or to point $S_{1, RS1, n}$) ($n = 1, 2, \ldots, NSK$)
RC	origin of the outer heat-shield radius (must be on the X-axis)
RS1	origin of the edge-ring 1 radius (must be on the X-axis)

RS2 — origin of the edge-ring 2 radius (must be on the X-axis)

RS3 — origin of the edge-ring 3 radius (must be on the X-axis)

r_{LBC} — radius which defines a ring containing the bolt-circle points (figs. 10 and B-3)

r_n — radius from the center of the heat shield to the ring (of points) n (n = 1, 2, . . ., NOOR) on the heat shield, in.

$S_{1,n}$ — points on the outer surface of the undeflected heat shield for which deflections are to be determined (n = 1, 2, . . ., NSK)

$S_{1,RS1,n}$ — points on the outer surface of undeflected edge ring 1 (n = 1, 2, . . ., 24)

$S_{1,RS2,n}$ — points on the outer surface of undeflected edge ring 2 (n = 1, 2, . . ., 24)

$S_{1,RS3,n}$ — points on the outer surface of undeflected edge ring 3 (n = 1, 2, . . ., 24)

$S_{H, MAX}$ — maximum stroke in the honeycomb shock struts

$S_{S, MAX}$ — maximum stroke in the spring shock struts

$SC1_n$ — first constant-crush level in the compression of honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$), lb

SC1S — constant-crush level in the compression of the couch-bumper shocks, lb

$SC2_n$ — second constant-crush level in the compression of honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$), lb

SE3M — left-side couch-bumper compression stroke, in.

SE3P — right-side couch-bumper compression stroke, in.

$SEVC3_n$ — strut compression stroke of honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$) at the start of a computer run, in.

SEVC3M — left-side couch-bumper compression stroke at the start of a computer run, in.

SEVC3P	right-side couch-bumper compression stroke at the start of a computer run, in.
$SEVT3_n$	strut tension stroke of honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$) at the start of a computer run, in.
$SHOCK_n$	shock strut connected to points $P_{1,n}$ and $P_{2,n}$ ($n = 2, \ldots, N + 1$)
$ST1_n$	first constant load tension level of honeycomb or cyclic-deformation $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$), lb
$ST2_n$	second constant load tension level of honeycomb $SHOCK_n$ ($n = N_{SS} + 2, \ldots, N + 1$), lb
$TF_{x,n}, TF_{y,n}, TF_{z,n}$	components along the i_n-, j_n-, and k_n-axes, respectively, of the total force acting on body n ($n = 1, 2$), lb
$TG_{x,n}, TG_{y,n}, TG_{z,n}$	components about the i'_n-, j'_n-, and k'_n-axes, respectively, of the total torque acting through $c.g._n$ ($n = 1, 2$), in-lb
t	time, sec
t_n	thickness of the stainless-steel face sheet on one side of the heat shield at point $S_{1,n}$ ($n = 1, 2, \ldots, NSK$) and point $S_{1,B,n}$ ($n = NSK + 1, \ldots, NSK + NBC$)
u''_n, v''_n, w''_n	components of the translational velocity vector of $c.g._n$ along the i_n-, j_n-, and k_n-axes ($n = 1, 2$), respectively, in/sec
V_N	initial velocity-vector component perpendicular to the $\bar{\bar{X}}\bar{\bar{Z}}$ plane, ft/sec
$V_{S,1,1}$	velocity component of point $S_{1,1}$ in the $\bar{\bar{X}}\bar{\bar{Z}}$ plane, in/sec
V_T	initial velocity-vector component parallel to the $\bar{\bar{X}}\bar{\bar{Z}}$ plane, ft/sec
VC_n	velocity component of $SHOCK_n$ ($n = 2, 3, \ldots, N + 1$) along the shock center line, in/sec

X, Y, Z	orthogonal Apollo reference-system axes
X_{AR}, Y_{AR}, Z_{AR}	components of the relative-displacement vector from $c.g._1$ to AR_o along the i_1-, j_1-, and k_1-axes, respectively, in.
X_n, Y_n, Z_n	components (parallel to the i_1-, j_1-, and k_1-axes) of the relative-displacement vector from point $P_{1,n}$ to point $P_{2,n}$ ($n = 1, 2, \ldots, N+1$), respectively, in.
$X_{p,1,n}, Y_{p,1,n}, Z_{p,1,n}$	components of the relative-displacement vector from $c.g._1$ to point $P_{1,n}$ ($n = 1, 2, \ldots, N+1$) along the i_1-, j_1-, and k_1-axes, respectively, in.
$X_{p,1+L}, X_{p,1-L}$	components of the relative-displacement vectors from $c.g._1$ to the right-side and left-side couch-bumper bearing plates, respectively, along the i_1-axis, in.
$X_{p,2,n}, Y_{p,2,n}, Z_{p,2,n}$	components of the relative-displacement vector from $c.g._2$ to point $P_{2,n}$ ($n = 1, 2, \ldots, N+1$) along the i_2-, j_2-, and k_2-axes, respectively, in.
$X_{p,2+L}, Y_{p,2+L}, Z_{p,2+L}$	components of the relative-displacement vector from $c.g._2$ to point P_{2+L} along the i_2-, j_2-, and k_2-axes, respectively, in.
$X_{p,2-L}, Y_{p,2-L}, Z_{p,2-L}$	components of the relative-displacement vector from $c.g._2$ to point P_{2-L} along the i_2-, j_2-, and k_2-axes, respectively, in.
X_{RC}	relative-displacement vector from AR_o to point RC along the X-axis, in.
$X_{S,1,n}, Y_{S,1,n}, Z_{S,1,n}$	components of the relative-displacement vector from AR_o to point $S_{1,n}$ parallel to the i_1-, j_1-, and k_1-axes (in the body 1 axis system) ($n = 1, 2, \ldots,$ NSK), respectively, in.
$X_{S,1,RS1,n}, Y_{S,1,RS1,n}, Z_{S,1,RS1,n}$	components parallel to the i_1-, j_1-, and k_1-axes (in the body 1 axis system) of the relative-displacement vector from AR_o to point $S_{1,RS1,n}$ ($n = 1, 2, \ldots,$ 24), respectively, in.

$X_{S,1,RS2,n}$, $Y_{S,1,RS2,n}$, $Z_{S,1,RS2,n}$ — components (in the body 1 axis system) of the relative-displacement vector from AR_0 to point $S_{1,RS2,n}$ parallel to the i_1-, j_1-, and k_1-axes (n = 1, 2, . . ., 24), respectively, in.

$X_{S,1,RS3,n}$, $Y_{S,1,RS3,n}$, $Z_{S,1,RS3,n}$ — components (in the body 1 axis system) of the relative-displacement vector from AR_0 to point $S_{1,RS3,n}$ parallel to the i_1-, j_1-, and k_1-axes (n = 1, 2, . . ., 24), respectively, in.

XR — relative-displacement vector from c.g.$_1$ to the edge of the CM along the j_1-axis, in.

$\bar{\bar{X}}, \bar{\bar{Y}}, \bar{\bar{Z}}$ — inertially fixed orthogonal axes or vectors directed along the X-, Y-, and Z-axes

$\bar{\bar{X}}_n$, $\bar{\bar{Y}}_n$, $\bar{\bar{Z}}_n$ — components of the c.g.$_n$ displacement vector along the $\bar{\bar{X}}$-, $\bar{\bar{Y}}$-, and $\bar{\bar{Z}}$-axes, respectively, in.

$\bar{\bar{X}}_{S,1,1}$, $\bar{\bar{Y}}_{S,1,1}$, $\bar{\bar{Z}}_{S,1,1}$ — components of the inertial displacement vector of point $S_{1,1}$, in.

$Y_{p,1+L}$, $Z_{p,1+L}$ — components of the relative-displacement vector from c.g.$_2$ to the point of application of P_{2+L} on the right-side couch-bumper bearing plate along the j_1- and k_1- axes, respectively, in.

$Y_{p,1-L}$, $Z_{p,1-L}$ — components of the relative-displacement vector from c.g.$_1$ to the point of application of P_{2-L} on the left-side couch-bumper bearing plate along the j_1- and k_1-axes, respectively, in.

YHSM — maximum ground penetration of the heat shield, in.

YR1M — maximum ground penetration of edge ring 1, in.

YR2M — maximum ground penetration of edge ring 2, in.

YR3M — maximum ground penetration of edge ring 3, in.

$\alpha_{1,n}$, $\alpha_{2,n}$, $\alpha_{3,n}$ — functions defined by equations (23), (24), and (25), respectively (n = 1, 2, . . ., N + 1)

β — vehicle stability angle, deg

Γ — an element of $[\Gamma]$

$[\Gamma]$ — matrix defined by equation (1)

$[\Gamma_n]$ — orthogonal transformation matrix for transforming vector components from the inertially fixed axis system to the arbitrarily oriented body n axis system (n = 1, 2)

$[\overline{\Gamma}]$ — orthogonal transformation matrix for transforming vector components from the arbitrarily oriented body 1 axes to the arbitrarily oriented body 2 axes

$\delta_{1,n}$ — deflection of point $S_{1,RS1,n}$ along a normal to the skin at point $S_{1,RS1,n}$ (n = 1, 2, . . ., 24) while moving from the current depth of penetration of the rigid structure to the ground-structure equilibrium position, in.

$\delta_{2,n}$ — deflection of point $S_{1,RS1,n}$ along a normal to the skin at point $S_{1,RS1,n}$ (n = 1, 2, . . ., 24) while moving from the current depth of penetration of the rigid structure to the unloaded ground line, in.

$\delta_{e,n}$ — structural deflection at point $S_{1,RS1,n}$ normal to a tangent plane at point $S_{1,RS1,n}$ (n = 1, 2, . . ., 24) when the ground and the structure are in equilibrium, in.

δ_n — structural deflection at point $S_{1,RS1,n}$ normal to a tangent plane at point $S_{1,RS1,n}$ (n = 1, 2, . . ., 24), in.

ν — Poisson ratio for the heat-shield facing material

Φ — angle, positive in the clockwise direction, that V_T makes with the negative $\overline{\overline{Z}}$-axis, deg

ϕ_n — angle from the 0° reference line to the radial line (of points) n (n = 1, 2, . . ., NOTHT) on the heat shield, deg

ψ, θ, ϕ — general Euler angles defining the angular orientation of the arbitrarily oriented body-fixed axis systems with respect to some other set of orthogonal axes, deg

ψ_n, θ_n, ϕ_n	Euler angles defining the angular orientation of the arbitrarily oriented body-fixed axes i_n, j_n, and k_n (n = 1, 2) with respect to the inertially fixed axes $\bar{\bar{X}}$, $\bar{\bar{Y}}$, and $\bar{\bar{Z}}$, deg
$\bar{\psi}, \bar{\theta}, \bar{\phi}$	Euler angles defining the angular orientation of the arbitrarily oriented body-fixed axes i_2, j_2, and k_2 with respect to the arbitrarily oriented body-fixed axes i_1, j_1, and k_1, deg
$\Omega_{x,1L}, \Omega_{y,1L}, \Omega_{z,1L}$	functions defined by equation (19)
$\Omega_{x,n}, \Omega_{y,n}, \Omega_{z,n}$	body n angular-velocity components about the i_n-, j_n-, and k_n-axes (n = 1, 2), respectively, deg/sec
$\Omega'_{x,n}, \Omega'_{y,n}, \Omega'_{z,n}$	body n angular-velocity components about the i'_n-, j'_n-, and k'_n-axes (n = 1, 2), respectively, deg/sec

Subscripts:

proj	indicates assumption that AC(1) is a square area followed by projection of AC(1) perpendicular to the vector $V_{S,1,1}$
RTS	vector components directed from RC to point $S_{1,1}$
$S_{1,1}$	values associated with point $S_{1,1}$

Operators:

$(\dot{\ })$	differentiation with respect to t
$(\ddot{\ })$	differentiation with respect to t^2
[ ]'	matrix transpose

ANALYSIS

This report is a result of the need for a method of determining the dynamic response of a falling body when it impacts a soil surface. The mathematical analysis presented in this report is general in scope and is applicable to a large class of dynamic-response problems which involve the nonlinear motion of two rigid bodies connected by deformable links and moving in free space, in a gravity field, or with a soil surface (subsequent to impact of one of the bodies with the soil surface and with one of the bodies in contact with the soil surface). The digital-computer program applies this analysis to the specific problem of determining the dynamic response of the Apollo CM to earth impact. The computer program provides for connection of as many as 19 deformable links between the two bodies and for monitoring of as many as 322 impact points on one of the bodies. The impact points are presently divided into 200 points on the CM heat shield, 50 points on the CM bolt circle (which attaches the heat shield to the CM inner structure), and 72 points on the outer edge of the CM. Although only the edge rings are considered to be deformable in this report, few computer-program changes would be required for application of the program to a deformable surface on the entire impacting body.

Axis Systems and General Vehicle Orientation

The general body orientation is shown in figure 1, and the specific body orientation selected for the sample CM problem is shown in figure 2. In the analysis which follows, body 1 will represent a CM structure without the crew couch, and body 2 will represent the crew couch.

Each body has two fixed orthogonal axis systems originating at its center of gravity. One of the axis systems within each body must be coincident with the body principal axes. The equations describing the body rotational motion are written with respect to this axis system and thus reduce to Euler equations. The angular orientation of the other axis system within each body is arbitrary but usually coincident with any existing geometrically symmetric axes. This arbitrarily oriented system is located in an inertial frame by the set of Euler angles defined in figure 3. Equations that describe the translational motion of a given body are always written with respect to the arbitrarily oriented axis system within the body. The two arbitrarily oriented systems (one in each body) are related to one another by a set of relative Euler angles which reduce to pitch, roll, and yaw for small angles (fig. 4). Within a given body, the two axis systems are related to each other by a set of direction cosines.

The computer program requires several coordinate transformations. To simplify the description of many of these transformations, the following general matrix will be required.

$$[\Gamma] = \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \Gamma_{13} \\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} \\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ -\sin\psi\cos\phi + \sin\phi\sin\theta\cos\psi & \cos\phi\cos\psi + \sin\phi\sin\theta\sin\psi & \sin\phi\cos\theta \\ \sin\phi\sin\phi + \cos\phi\sin\theta\cos\psi & -\sin\phi\cos\psi + \cos\phi\sin\theta\sin\psi & \cos\phi\cos\theta \end{bmatrix} \tag{1}$$

The principal body axes are related to the arbitrarily oriented axes in the same body by

$$\begin{Bmatrix} i_n \\ j_n \\ k_n \end{Bmatrix} = \left[\ell_n\right] \begin{Bmatrix} i'_n \\ j'_n \\ k'_n \end{Bmatrix} \tag{2}$$

where $n = 1, 2$; and $[\ell_n]$ is given by

$$\left[\ell_n\right] = \begin{bmatrix} \bar{i}_n \cdot \bar{i}'_n & \bar{i}_n \cdot \bar{j}'_n & \bar{i}_n \cdot \bar{k}'_n \\ \bar{j}_n \cdot \bar{i}'_n & \bar{j}_n \cdot \bar{j}'_n & \bar{j}_n \cdot \bar{k}'_n \\ \bar{k}_n \cdot \bar{i}'_n & \bar{k}_n \cdot \bar{j}'_n & \bar{k}_n \cdot \bar{k}'_n \end{bmatrix} \tag{3}$$

The inertial axes are related to the arbitrarily oriented body axes by

$$\begin{Bmatrix} i_n \\ j_n \\ k_n \end{Bmatrix} = \left[\Gamma_n\right] \begin{Bmatrix} \bar{\bar{X}} \\ \bar{\bar{Y}} \\ \bar{\bar{Z}} \end{Bmatrix} \tag{4}$$

where $n = 1, 2$; and $\left[\Gamma_n\right]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = \left[\Gamma_n\right]$, $\Gamma_{mp} = \Gamma_{mp,n}$, $\psi = \psi_n$, $\theta = \theta_n$, and $\phi = \phi_n$ where $m = 1, 2, 3$ and $p = 1, 2, 3$. The arbitrarily oriented body axes of body 1 are related to the arbitrarily oriented body axes of body 2 by

$$\begin{Bmatrix} i_2 \\ j_2 \\ k_2 \end{Bmatrix} = [\overline{\Gamma}] \begin{Bmatrix} i_1 \\ j_1 \\ k_1 \end{Bmatrix} \tag{5}$$

where $[\bar{\Gamma}]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = [\bar{\Gamma}]$, $\Gamma_{mp} = \bar{\Gamma}_{mp}$, $\theta = \bar{\theta}$, $\psi = \bar{\psi}$, and $\phi = \bar{\phi}$ where $m = 1, 2, 3$ and $p = 1, 2, 3$.

Equations of Motion

The equations used in the computer program place no restrictions (within the limitations imposed by physical interference) on either angular or translational displacement of the two bodies relative to an inertial frame or to each other. The bodies may also have completely general geometric and inertial properties.

The equations of rotational motion used in the computer program are

$$I_{i',n}\dot{\Omega}'_{x,n} - \Omega'_{y,n}\Omega'_{z,n}\left(I_{j',n} - I_{k',n}\right) = TG_{x,n} \tag{6}$$

$$I_{j',n}\dot{\Omega}'_{y,n} - \Omega'_{x,n}\Omega'_{z,n}\left(I_{k',n} - I_{i',n}\right) = TG_{y,n} \tag{7}$$

$$I_{k',n}\dot{\Omega}'_{z,n} - \Omega'_{x,n}\Omega'_{y,n}\left(I_{i',n} - I_{j',n}\right) = TG_{z,n} \tag{8}$$

where $n = 1, 2$. Integration of these equations yields $\Omega'_{x,n}$, $\Omega'_{y,n}$, and $\Omega'_{z,n}$. Body n angular-velocity components about the arbitrarily oriented body axes can be obtained from

$$\begin{Bmatrix} \Omega_{x,n} \\ \Omega_{y,n} \\ \Omega_{z,n} \end{Bmatrix} = \left[\ell_n\right] \begin{Bmatrix} \Omega'_{x,n} \\ \Omega'_{y,n} \\ \Omega'_{z,n} \end{Bmatrix} \tag{9}$$

where $n = 1, 2$.

The equations of translational motion for body n are

$$M_n \dot{u}_n'' + M_n\left(\Omega_{y,n} w_n'' - \Omega_{z,n} v_n''\right) = TF_{x,n} \tag{10}$$

$$M_n \dot{v}_n'' + M_n\left(\Omega_{z,n} u_n'' - \Omega_{x,n} w_n''\right) = TF_{y,n} \tag{11}$$

$$M_n \dot{w}_n'' + M_n\left(\Omega_{x,n} v_n'' - \Omega_{y,n} u_n''\right) = TF_{z,n} \tag{12}$$

where $n = 1, 2$. Integration of these equations yields u_n'', v_n'', and w_n''.

The time rates of change of the inertial Euler angles for body n are given by

$$\dot{\theta}_n = \Omega_{y,n} \cos \phi_n - \Omega_{z,n} \sin \phi_n \tag{13}$$

$$\dot{\phi}_n = \Omega_{x,n} + \tan \theta_n \left(\Omega_{y,n} \sin \phi_n + \Omega_{z,n} \cos \phi_n\right) \tag{14}$$

$$\dot{\psi}_n = \frac{\left(\Omega_{y,n} \sin \phi_n + \Omega_{z,n} \cos \phi_n\right)}{\cos \theta_n} \tag{15}$$

where $n = 1, 2$. Integration of these equations results in the Euler angles shown in figure 3. The time rates of change of the relative Euler angles are given by

$$\dot{\overline{\theta}} = \left(\Omega_{y,2} - \Omega_{y,1L}\right)\cos \overline{\phi} - \left(\Omega_{z,2} - \Omega_{z,1L}\right)\sin \overline{\phi} \tag{16}$$

$$\dot{\overline{\phi}} = \left(\Omega_{x,2} - \Omega_{x,1L}\right) + \tan \overline{\theta} \left[\left(\Omega_{y,2} - \Omega_{y,1L}\right)\sin \overline{\phi} + \left(\Omega_{z,2} - \Omega_{z,1L}\right)\cos \overline{\phi}\right] \tag{17}$$

$$\dot{\overline{\Psi}} = \frac{\left[\left(\Omega_{y,2} - \Omega_{y,1L}\right)\sin \overline{\phi} + \left(\Omega_{z,2} - \Omega_{z,1L}\right)\cos \overline{\phi}\right]}{\cos \overline{\theta}} \tag{18}$$

where

$$\begin{Bmatrix} \Omega_{x,1L} \\ \Omega_{y,1L} \\ \Omega_{z,1L} \end{Bmatrix} = [\overline{\Gamma}] \begin{Bmatrix} \Omega_{x,1} \\ \Omega_{y,1} \\ \Omega_{z,1} \end{Bmatrix} \tag{19}$$

Integration of equations (16), (17), and (18) yields the relative Euler angles.

Within the arbitrarily oriented body 1 axis system, components of the time rate of change of $\overline{P_{1,n}P_{2,n}}$ are given by

$$\begin{aligned} \dot{X}_n = {} & Y_n\Omega_{z,1} - Z_n\Omega_{y,1} - u_1'' - Z_{p,1,n}\Omega_{y,1} + Y_{p,1,n}\Omega_{z,1} \\ & + \overline{\Gamma}_{11}\alpha_{1,n} + \overline{\Gamma}_{21}\alpha_{2,n} + \overline{\Gamma}_{31}\alpha_{3,n} \end{aligned} \tag{20}$$

$$\begin{aligned} \dot{Y}_n = {} & Z_n\Omega_{x,1} - X_n\Omega_{z,1} - v_1'' - X_{p,1,n}\Omega_{z,1} + Z_{p,1,n}\Omega_{x,1} \\ & + \overline{\Gamma}_{12}\alpha_{1,n} + \overline{\Gamma}_{22}\alpha_{2,n} + \overline{\Gamma}_{32}\alpha_{3,n} \end{aligned} \tag{21}$$

$$\begin{aligned} \dot{Z}_n = {} & X_n\Omega_{y,1} - Y_n\Omega_{x,1} - w_1'' - Y_{p,1,n}\Omega_{x,1} + X_{p,1,n}\Omega_{y,1} \\ & + \overline{\Gamma}_{13}\alpha_{1,n} + \overline{\Gamma}_{23}\alpha_{2,n} + \overline{\Gamma}_{33}\alpha_{3,n} \end{aligned} \tag{22}$$

where $n = 1, 2, \ldots, N + 1$ and

$$\alpha_{1,n} = u_2'' + Z_{p,2,n}\Omega_{y,2} - Y_{p,2,n}\Omega_{z,2} \tag{23}$$

$$\alpha_{2,n} = v_2'' + X_{p,2,n}\Omega_{z,2} - Z_{p,2,n}\Omega_{x,2} \tag{24}$$

$$\alpha_{3,n} = w_2'' + Y_{p,2,n}\Omega_{x,2} - X_{p,2,n}\Omega_{y,2} \tag{25}$$

Integration of equations (20), (21), and (22) yields the components of the relative-displacement vector from point $P_{1,n}$ to point $P_{2,n}$.

Force and Moment Equations

As stated previously, body 1 represents a CM structure without its crew couch. The forces acting on body 1 are the stroking forces of the interconnecting shock struts, ground-impact forces, and gravity forces.

The forces acting on body 2 (the crew couch) are caused by shock-strut stroking and gravity. The shock-strut-stroking forces are considered first. The three kinds of shock struts that may be simulated by the computer program are spring-damper shock struts, honeycomb shock struts, and cyclic-deformation shock struts. The spring force developed in the spring-damper shock struts is given by

$$FK_n = CK_n\left(\left|\overline{P_{1,n}P_{2,n}}\right| - CL_n\right) \tag{26}$$

where $n = 2, \ldots, N + 1$. Energy absorption per cycle caused by damping is expressed by the following nonviscous-fluid damping term

$$FD_n = CD_n\left(VC_n\right)\left(\left|VC_n\right|\right) \tag{27}$$

where $n = 2, \ldots, N + 1$; and VC_n is given by

$$VC_n = \frac{X_n\dot{X}_n + Y_n\dot{Y}_n + Z_n\dot{Z}_n}{\left|\overline{P_{1,n}P_{2,n}}\right|} \tag{28}$$

where $n = 2, \ldots, N + 1$; and FD_n and FK_n are directed along $SHOCK_n$ with signs determined by the arbitrary axes of body 1. Equations (26), (27), and (28) apply indirectly to the other two types of shock struts, as explained in the following paragraph.

Assume that FK_n represents the force generated by the crushing of honeycomb in the shock strut. Such a force may be determined numerically by the computer program, which computes $\left|\overline{P_{1,n}P_{2,n}}\right|$ and uses this value (together with the value saved from the last integration step) to locate the corresponding honeycomb force in a table generated by the computer from a curve of the type shown in figure 5. Coulomb damping in the strut is represented by FD_n. This type of damping results in a constant friction force that acts on the strut (whenever it is in motion) in a direction opposite to the instantaneous strut velocity. The computer program is capable of handling four discrete values of FD_n for each strut. These values depend on the direction of the stroking and on whether the stroking is taking place in the head end of the cylinder. A table in the computer program may be used at any time to obtain FD_n as a function of instantaneous strut length and velocity. A visual representation of the combined action of honeycomb crushing and friction force is shown in figure 6.

If the user requires a simulation of cyclic-deformation stroking, FK_n represents the force generated when the strut material is deformed by motion of one end of the strut relative to the other strut. The force FK_n is determined numerically by the computer program. The computer determines the current value of $\left|\overline{P_{1,n}P_{2,n}}\right|$ and uses the value (together with the value saved from the last integration step) to locate the correct deformation force in a table generated by the computer from a curve of the type shown in figure 7. The structural damping in the strut FD_n is expressed by the following damping term

$$FD_n = C_{ST}\left(VC_n\right) \tag{29}$$

where $n = 2, \ldots, N + 1$. The components of force caused by $SHOCK_n$ acting on body 1 at point $P_{1,n}$ are given by

$$F_{x,1}C_n = \left(FK_n + FD_n\right)\frac{X_n}{\left|\overline{P_{1,n}P_{2,n}}\right|} \tag{30}$$

$$F_{y,1}C_n = \left(FK_n + FD_n\right)\frac{Y_n}{\left|\overline{P_{1,n}P_{2,n}}\right|} \tag{31}$$

$$F_{z,1}C_n = \left(FK_n + FD_n\right)\frac{Z_n}{\left|\overline{P_{1,n}P_{2,n}}\right|} \tag{32}$$

where $n = 2, \ldots, N + 1$.

The shock force acting on body 2 will be equal and opposite to the shock force on body 1. The components of force (in the arbitrarily oriented body 2 axis system) caused by $SHOCK_n$ acting on body 2 at point $P_{2,n}$ are given by

$$\begin{Bmatrix} F_{x,2}C_n \\ F_{y,2}C_n \\ F_{z,2}C_n \end{Bmatrix} = -[\overline{T}]\begin{Bmatrix} F_{x,1}C_n \\ F_{y,1}C_n \\ F_{z,1}C_n \end{Bmatrix} \tag{33}$$

where $n = 2, \ldots, N + 1$. The components of torque (in the arbitrarily oriented body 1 axis system), acting through $c.g._1$ and caused by $SHOCK_n$ acting at point $P_{1,n}$, are given by

$$G_{x,1,n} = Y_{p,1,n}\left(F_{z,1}C_n\right) - Z_{p,1,n}\left(F_{y,1}C_n\right) \tag{34}$$

$$G_{y,1,n} = Z_{p,1,n}\left(F_{x,1}C_n\right) - X_{p,1,n}\left(F_{z,1}C_n\right) \tag{35}$$

$$G_{z,1,n} = X_{p,1,n}\left(F_{y,1}C_n\right) - Y_{p,1,n}\left(F_{x,1}C_n\right) \tag{36}$$

where $n = 2, \ldots, N + 1$. Similarly, for body 2

$$G_{x,2,n} = Y_{p,2,n}\left(F_{z,2}C_n\right) - Z_{p,2,n}\left(F_{y,2}C_n\right) \tag{37}$$

$$G_{y,2,n} = Z_{p,2,n}\left(F_{x,2}C_n\right) - X_{p,2,n}\left(F_{z,2}C_n\right) \tag{38}$$

$$G_{z,2,n} = X_{p,2,n}\left(F_{y,2}C_n\right) - Y_{p,2,n}\left(F_{x,2}C_n\right) \tag{39}$$

where $n = 2, \ldots, N + 1$.

The computer program provides for two honeycomb couch bumpers, which are constrained to deform in compression only in a direction parallel to the i_2-axis. The tips of the bumpers are located as shown in figure 8. To determine the bumper forces and torque acting on the system at any given time step, the computer program first establishes which, if any, bumper tip is penetrating a bearing plate. If, for example, interference exists between point P_{2+L} and the right-side bearing plate, the computer program will stroke the bumper parallel to the i_2-axis until P_{2+L} lies on the bearing plate. The force in the bumper acting on body 2 $F_{B,i,2}$ can then be located in a table generated by the computer from a curve of the type shown in figure 9.

Note that $F_{B,j,2}$ and $F_{B,k,2}$ both equal zero and that $F_{B,i,2}$ is negative for right-bumper contact. The point of application of point P_{2+L} on the right bearing plate $\left(X_{p,1+L}, Y_{p,1+L}, Z_{p,1+L}\right)$ is computed in the arbitrarily oriented body 1 axis system. The components of force in the same axis system that are due to the couch bumper acting on body 1 are given by

$$\begin{Bmatrix} F_{B,i,1} \\ F_{B,j,1} \\ F_{B,k,1} \end{Bmatrix} = -[\overline{\Gamma}]' \begin{Bmatrix} F_{B,i,2} \\ 0 \\ 0 \end{Bmatrix} \tag{40}$$

The components of torque (in the arbitrarily oriented body 2 axis system), acting through $c.g._2$ and caused by the couch bumper acting at point P_{2+L}, are given by

$$G_{B,i,2} = 0 \tag{41}$$

$$G_{B,j,2} = Z_{p,2+L}\left(F_{B,i,2}\right) \tag{42}$$

$$G_{B,k,2} = -Y_{p,2+L}\left(F_{B,i,2}\right) \tag{43}$$

The components of torque (in the arbitrarily oriented body 1 axis system), acting through $c.g._1$ and caused by the couch bumper acting at point P_{2+L}, are given by

$$G_{B,i,1} = Y_{p,1+L}\left(F_{B,k,1}\right) - Z_{p,1+L}\left(F_{B,j,1}\right) \tag{44}$$

$$G_{B,j,1} = Z_{p,1+L}\left(F_{B,i,1}\right) - X_{p,1+L}\left(F_{B,k,1}\right) \tag{45}$$

$$G_{B,k,1} = X_{p,1+L}\left(F_{B,j,1}\right) - Y_{p,1+L}\left(F_{B,i,1}\right) \tag{46}$$

To compute the ground-impact forces acting on body 1, the CM structure is divided into two distinct load-carrying areas, the heat shield and the outer edge (or toe) of the structure, which extends beyond the heat shield. The heat shield is a spherical surface with a radius originating at RC and will be considered first.

Several points are located on the heat shield in polar coordinates. The points are numbered clockwise and outward, beginning at the intersection line ϕ_8 and ring 1 (fig. 10). The outermost ring of points is located at the edge of the heat shield. A ring of points must also be located at the bolt circle, where the heat shield is mounted to the pressure shell. These bolt-circle points must be assigned higher numbers than any other points on the heat shield. All the information required to locate these points is loaded into the computer and stored in the computer memory. To compute soil loads on the skin, a portion of the heat-shield area is assigned to each point, except for points on the bolt circle. Because the heat shield is considered simply to be supported at the bolt circle, loads there do not contribute to heat-shield bending.

Figure 10 indicates the manner in which the areas are assigned to the points. (Radii and angles bounding the areas are selected midway between adjacent heat-shield points, excluding the bolt-circle points.) At a given instant, the computer program will determine which heat-shield points are below the $\bar{\bar{X}}\bar{\bar{Z}}$ (inertial) plane, that is, below the undeformed soil surface. Assume, for example, that point $S_{1,1}$ is below the $\bar{\bar{X}}\bar{\bar{Z}}$ plane and has a soil force acting on it (fig. 11). The point is located in the inertial system by coordinates $\bar{\bar{X}}_{S,1,1}$, $\bar{\bar{Y}}_{S,1,1}$, and $\bar{\bar{Z}}_{S,1,1}$. The coordinate $\bar{\bar{Y}}_{S,1,1}$ gives the current depth of penetration into the soil. The computer also has available in memory the previous depth of penetration of point $S_{1,1}$, as well as the permanent soil deformation, if any, associated with the point. The inertial-velocity components $\left(\dot{\bar{\bar{X}}}_{S,1,1}, \dot{\bar{\bar{Y}}}_{S,1,1}, \text{and } \dot{\bar{\bar{Z}}}_{S,1,1}\right)$ of point $S_{1,1}$ are computed from the translational and rotational velocities of body 1. The resultant horizontal-velocity component $V_{S,1,1}$ (parallel to the $\bar{\bar{X}}\bar{\bar{Z}}$ plane) is then computed. The soil forces acting at point $S_{1,1}$ are broken down into horizontal and vertical components, both of which consist of static-force and dynamic-force terms. The equations used are obtained from reference 1. The manner in which both static and dynamic vertical soil forces vary with penetration depth and velocity is indicated in figure 12.

The equation for the static vertical force at point $S_{1,1}$ (assuming a loading condition) is

$$\mathrm{FVS(1)} = (0.09)(\mathrm{GC\text{Ø}NST})[\mathrm{AC(1)}]\,[\mathrm{PENETRATION(1)}]^{\mathrm{GPOWER}} \tag{47}$$

The equation for the dynamic vertical force at point $S_{1,1}$ prior to soil-wedge formation is

$$\mathrm{FVD(1)} = (0.09)(\mathrm{AKNT})[\mathrm{PENETRATION(1)}]\,[\mathrm{AC(1)}] \tag{48}$$

After soil-wedge formation, this force becomes

$$\mathrm{FVD(1)} = (0.5)(\mathrm{DENSTY})[\mathrm{AC(1)}](\mathrm{AKC})\left(\dot{\bar{\bar{Y}}}_{S,1,1}\right)^2 \tag{49}$$

The total vertical soil force at point $S_{1,1}$ is given by

$$FVT(1) = FVS(1) + FVD(1) \tag{50}$$

For the computation of the horizontal component of soil force at point $S_{1,1}$, the area AC(1) is assumed to be square and projected perpendicular to the vector $V_{S,1,1}$. This projected area is then used in the equations for the horizontal soil force.

The equation for the static horizontal force at point $S_{1,1}$ is

$$FHS(1) = CGO(DENSTY)[PENETRATION(1)]AC(1)_{proj}(\tan FA) \tag{51}$$

The equation for the dynamic horizontal force at point $S_{1,1}$ is

$$FHD(1) = CDO(DENSTY)\left[AC(1)_{proj}\right]\left(V_{S,1,1}\right)^2 \tag{52}$$

The total horizontal soil force at point $S_{1,1}$ consists of the drag forces given previously and a friction-force term that follows.

$$FD(1) = FHS(1) + FHD(1) + (AMU)[FVT(1)] \tag{53}$$

The friction force is resolved into components $FD(1)_{\overline{\overline{X}}}$ and $FD(1)_{\overline{\overline{Z}}}$ along the $\overline{\overline{X}}$ and $\overline{\overline{Z}}$ inertial axes, respectively. In the arbitrarily oriented body 1 axis system, the components of soil force acting at point $S_{1,n}$ are given by

$$\begin{Bmatrix} FS_{i,1,n} \\ FS_{j,1,n} \\ FS_{k,1,n} \end{Bmatrix} = \left[\Gamma_1\right] \begin{Bmatrix} FD(n)_{\overline{\overline{X}}} \\ FVT(n) \\ FD(n)_{\overline{\overline{Z}}} \end{Bmatrix} \tag{54}$$

where $n = 1, 2, \ldots, NSK$.

The components of torque (in the arbitrarily oriented body 1 axis system), acting through c.g.$_1$ and caused by the soil forces acting at point $S_{1,n}$, are given by

$$\begin{Bmatrix} GS_{i,1,n} \\ GS_{j,1,n} \\ GS_{k,1,n} \end{Bmatrix} = \overrightarrow{R_{S,n}} \times \begin{Bmatrix} FS_{i,1,n} \\ FS_{j,1,n} \\ FS_{k,1,n} \end{Bmatrix} \qquad (55)$$

where n = 1, 2, . . . , NSK.

The geometry is shown in figure 13. The three edge rings are simulated by conical frustums with arbitrarily selected heights. The rings are located relative to the X-axis by imaginary cones with slant heights that are perpendicular to the edge-ring slant heights and that intersect them at their midpoints. All three rings have 24 points, numbered identically. The points comprising each ring are equally spaced and have equal areas. The ring-point numbering system is related to the heat-shield-point numbering system, as indicated in figure 13.

The data required to locate the edge-ring points and the areas assigned to the points are loaded into the computer and stored in the computer memory. Two options are available for loading the edge-ring data. For the first option, the edge rings are considered to be rigid and are handled in the manner prescribed for the heat shield. The second option permits edge-ring deformation as well as ground deformation. A load-stroke curve of the type shown in figure 14 is assigned to each ring. At each time step, an iterative procedure in the computer program determines the equilibrium position between the ground and each edge point in contact with the ground. A curve of the type shown in figure 15 is constructed by the computer program for each point in contact with the ground. By assuming the structure to be rigid, a value y of FSN(n) may be obtained from the dot product of FSR(n) and a unit vector normal to the edge ring at $S_{1,RS1,n}$. The value $\delta_{1,n}$ may then be determined from the current depth of penetration of point $S_{1,RS1,n}$ and the previous ground-structure equilibrium position saved in the computer memory from the last integration step. The value x of FSN(n) (corresponding to $\delta_{1,n}$) may now be obtained from the soil-force equations, if the velocity of point $S_{1,RS1,n}$ at a deflection of $\delta_{1,n}$ is assumed to be the same as the velocity at the undeflected position (because $\delta_{1,n} << |R_{S,n}|$). Given the value x of FVS(n), deflection $\delta_{2,n}$ may be derived from the slope BOFF of the unloading curve, because any further structural deformation from the previous equilibrium position will result in unloading of the soil force.

The next step is to superimpose the load-stroke curve (fig. 14) for the edge-ring point onto the FSN(n) versus δ_n curve. The intersection point of the two curves, determined numerically by the computer, represents the structural deflection $\delta_{e,n}$

required for the ground and the structure to be in equilibrium. The computer provides for the intersection of either the loading ramp or the constant level (FR1) of the structure curve with either of the two sections of the FSN(n) versus δ_n curve. The case of an undeformed structure falling between the unloaded ground line and the previous equilibrium position is handled similarly.

Whether the edge rings are considered to be rigid or flexible, the result of the analysis will be force and moment equations similar to equation (54). In the arbitrarily oriented body 1 axis system, the components of torque acting through $c.g._1$ and caused by the couch-bumper, shock-strut, and soil forces are given by

$$c.g._{x,1} = \sum_{n=2}^{N+1} G_{x,1,n} + G_{B,i,1} + \sum_{n=1}^{NSK} GS_{i,1,n} \tag{56}$$

$$c.g._{y,1} = \sum_{n=2}^{N+1} G_{y,1,n} + G_{B,j,1} + \sum_{n=1}^{NSK} GS_{j,1,n} \tag{57}$$

$$c.g._{z,1} = \sum_{n=2}^{N+1} G_{z,1,n} + G_{B,k,1} + \sum_{n=1}^{NSK} GS_{k,1,n} \tag{58}$$

respectively. Similarly, for body 2

$$c.g._{x,2} = \sum_{n=2}^{N+1} G_{x,2,n} + G_{B,i,2} \tag{59}$$

$$c.g._{y,2} = \sum_{n=2}^{N+1} G_{y,2,n} + G_{B,j,2} \tag{60}$$

$$c.g._{z,2} = \sum_{n=2}^{N+1} G_{z,2,n} + G_{B,k,2} \tag{61}$$

The components of the total torque acting through $c.g._n$ may now be transformed to the principal axes as follows.

$$\begin{Bmatrix} TG_{x,n} \\ TG_{y,n} \\ TG_{z,n} \end{Bmatrix} = \left[\ell_n\right]' \begin{Bmatrix} c.g._{x,n} \\ c.g._{y,n} \\ c.g._{z,n} \end{Bmatrix} \tag{62}$$

where n = 1, 2. The components of the total force acting on body 2 along the arbitrarily oriented body axes are given by

$$TF_{x,2} = \sum_{n=2}^{N+1} F_{x,2}C_n + F_{B,i,2} + FG_{i,2} \tag{63}$$

$$TF_{y,2} = \sum_{n=2}^{N+1} F_{y,2}C_n + FG_{j,2} \tag{64}$$

$$TF_{z,2} = \sum_{n=2}^{N+1} F_{z,2}C_n + FG_{k,2} \tag{65}$$

The components of the gravity force acting on body n along the arbitrarily oriented body axes are given by

$$\begin{Bmatrix} FG_{i,n} \\ FG_{j,n} \\ FG_{k,n} \end{Bmatrix} = M_n\left[\Gamma_n\right] \begin{Bmatrix} G_{\overline{\overline{X}}} \\ G_{\overline{\overline{Y}}} \\ G_{\overline{\overline{Z}}} \end{Bmatrix} \tag{66}$$

where n = 1, 2. The components of the total force acting on body 1 along the arbitrarily oriented body axes may now be obtained from

$$TF_{x,1} = \left[\sum_{n=2}^{N+1} F_{x,1}C_n\right] + F_{B,i,1} + \sum_{n=1}^{NSK} FS_{i,1,n} + FG_{i,1} \tag{67}$$

$$TF_{y,1} = \left[\sum_{n=2}^{N+1} F_{y,1}C_n\right] + F_{B,j,1} + \sum_{n=1}^{NSK} FS_{j,1,n} + FG_{j,1} \tag{68}$$

$$TF_{z,1} = \left[\sum_{n=2}^{N+1} F_{z,1}C_n\right] + F_{B,k,1} + \sum_{n=1}^{NSK} FS_{k,1,n} + FG_{k,1} \tag{69}$$

CONCLUDING REMARKS

This report presents the six-degree-of-freedom rigid-body equations of motion for each of two bodies connected by shock struts and subjected to ground impact. A basic digital-computer program was presented for determining the dynamic response of the complete configuration subjected to gravity, strut-deformation, and soil-impact forces. The digital-computer program was written in subroutine form to facilitate the addition of equations representing other hardware and impact surfaces.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, April 15, 1971
914-50-20-17-72

REFERENCE

1. Black, R. J.; and Winters, H. K.: A Semiempirical Model for Prediction of Soil Reactive Forces and Footpad Penetrations for Spacecraft Landings. ECD No. AM-67-3, Bendix Corp., Analytical Mechanics Dept., South Bend, Ind., June 1967.

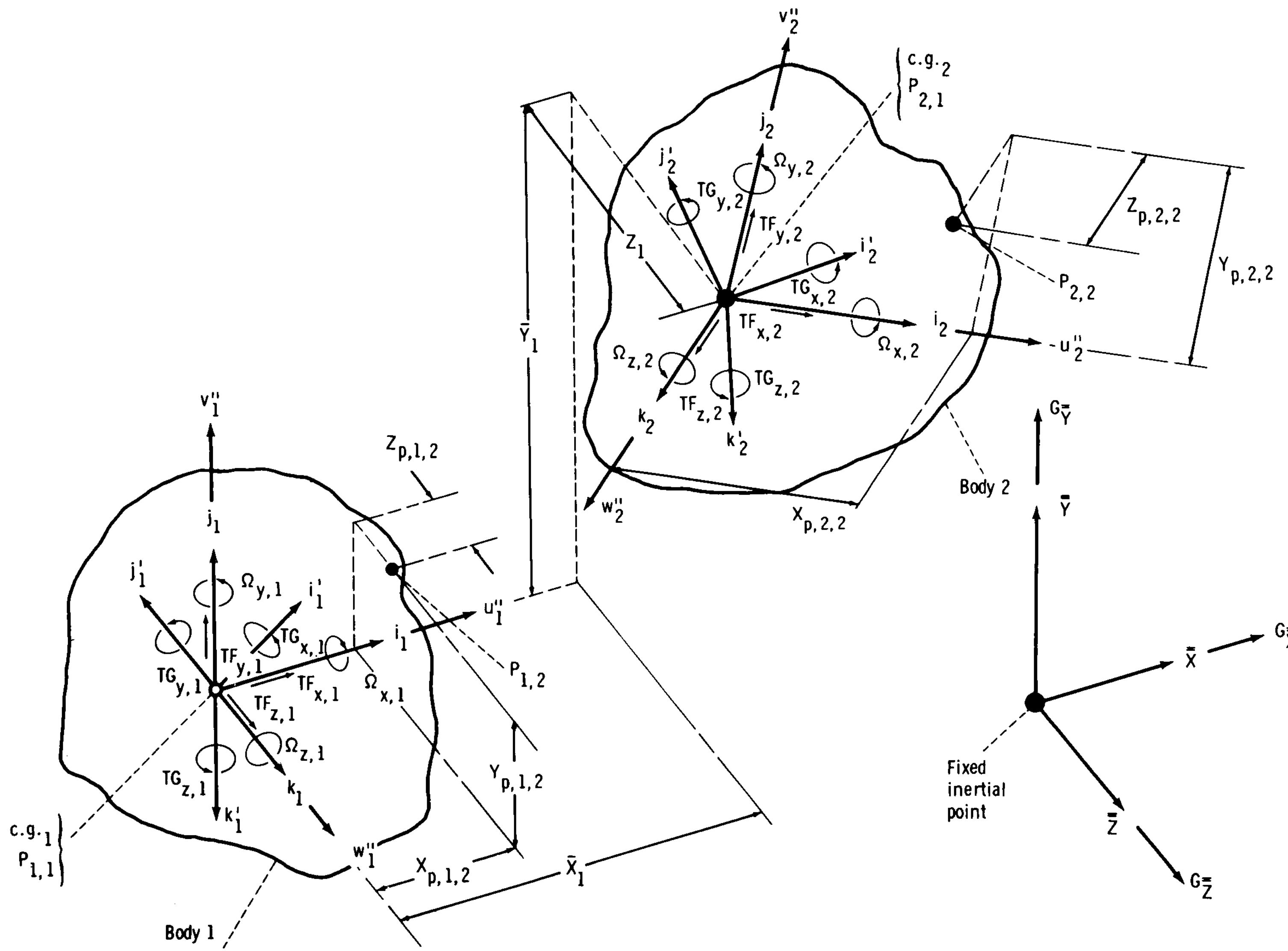
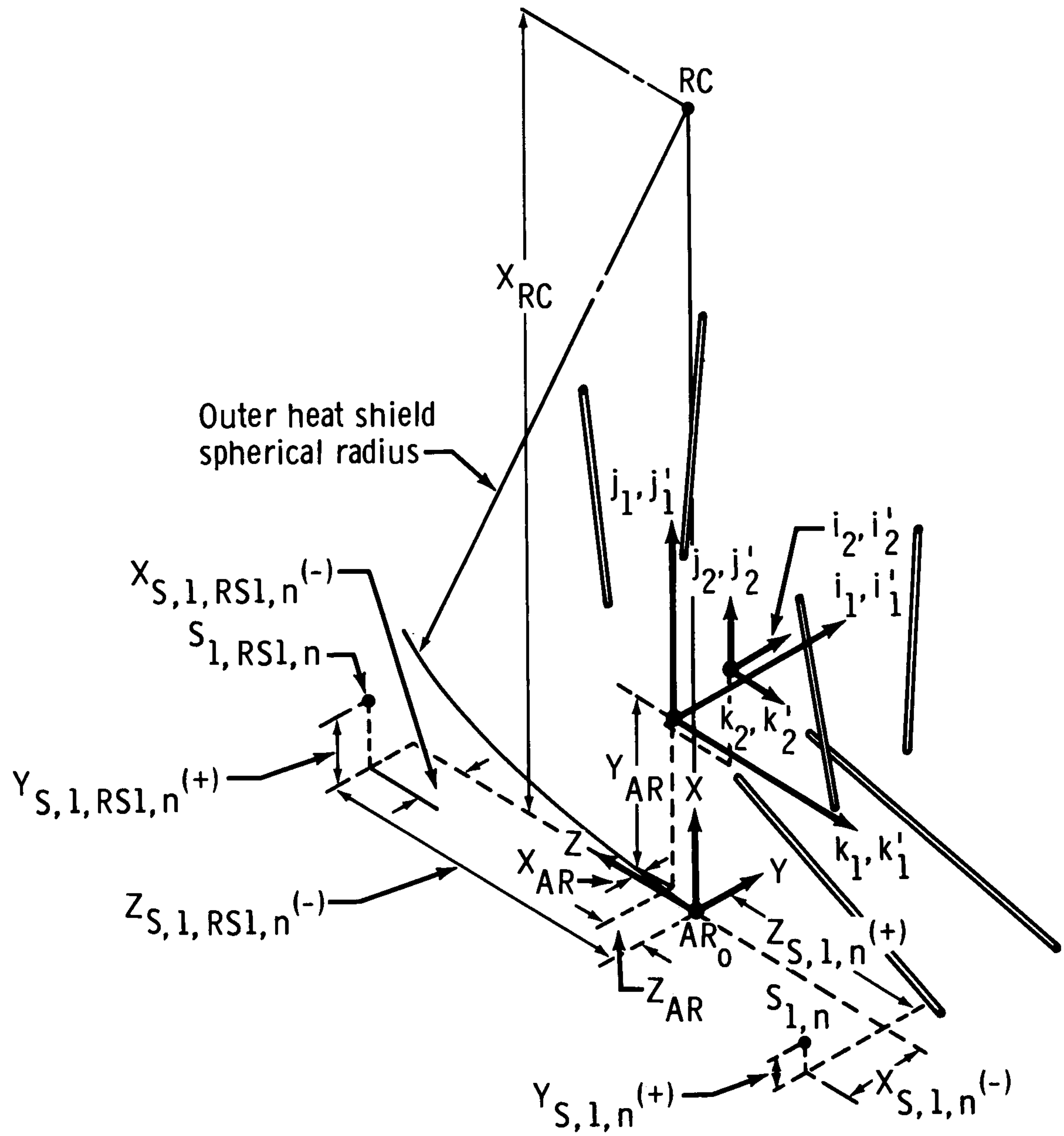


Figure 1. - General body orientation.



Note:

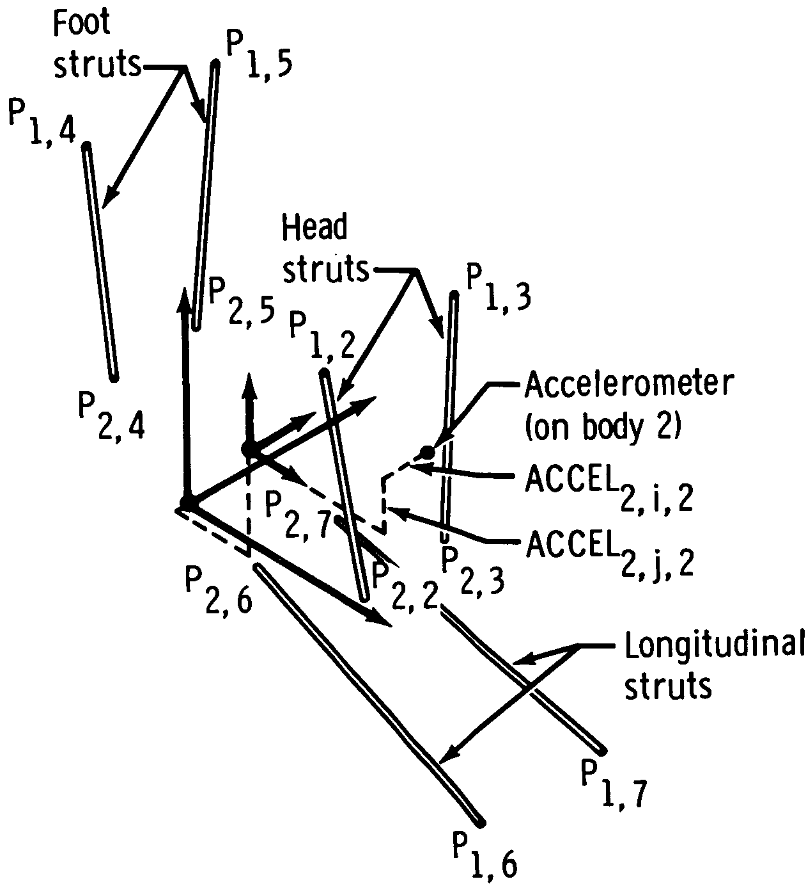
Point AR_0 is on the outer surface of the heat shield and on the CM axis of symmetry.

The i_1-, j_1-, k_1- axes are parallel to the Y-, X-, Z- axes, respectively.

The i_1-, j_1-, k_1- axes are parallel to the i_2-, j_2-, k_2- axes, respectively.

(a) Axis orientation selected for current CM studies.

Figure 2. - Axis orientation selected for current CM studies with approximate crew-couch-strut locations.



(b) Crew-couch struts.

Figure 2. - Concluded.

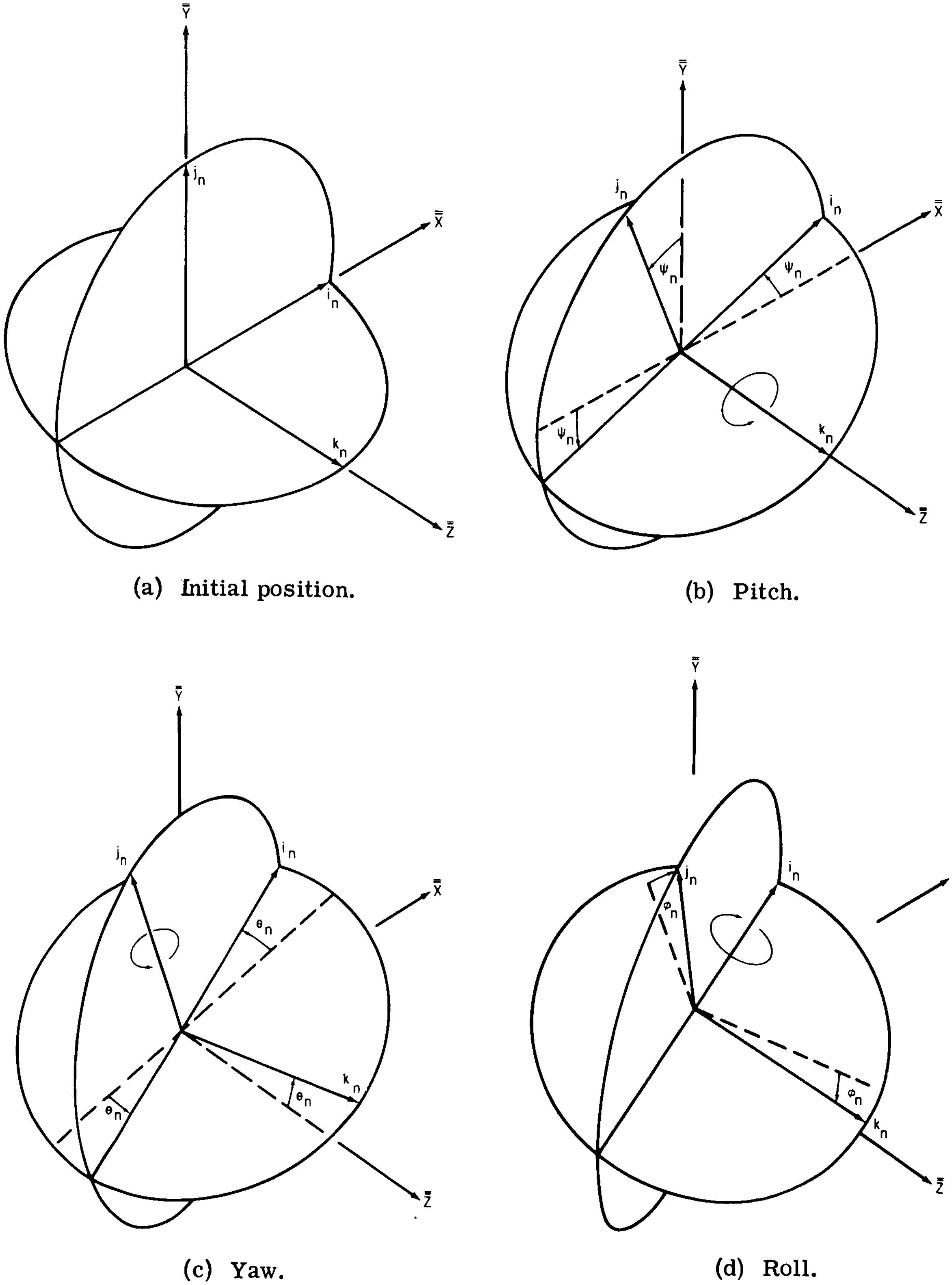
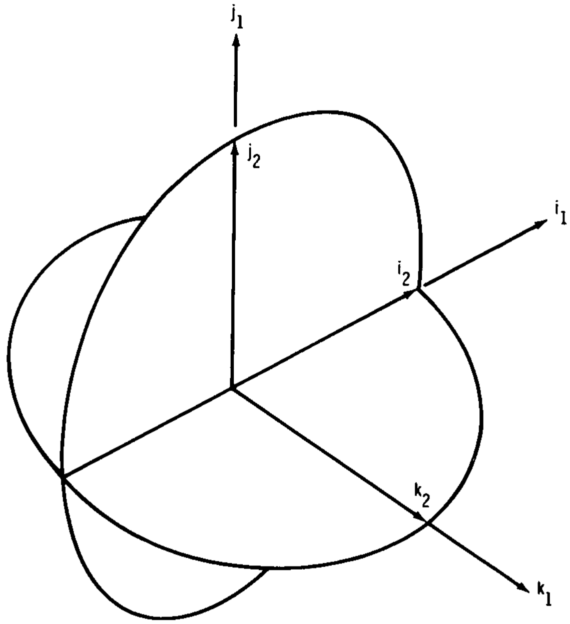
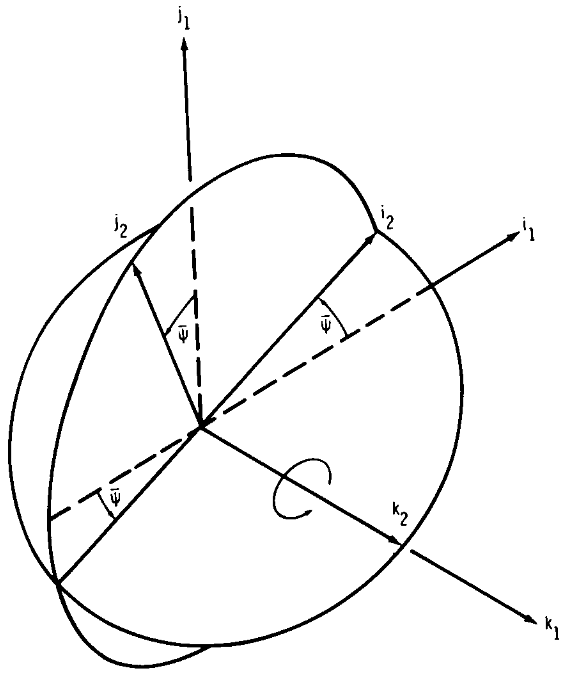


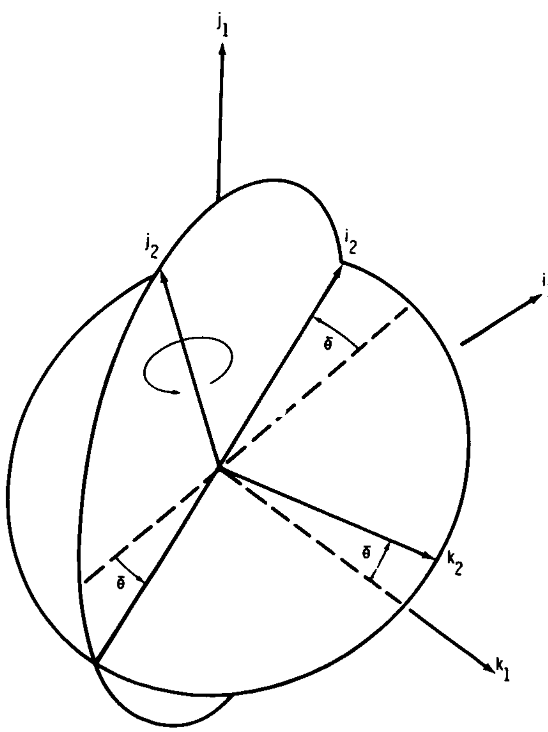
Figure 3. - Order of rotation for the inertial Euler angles.



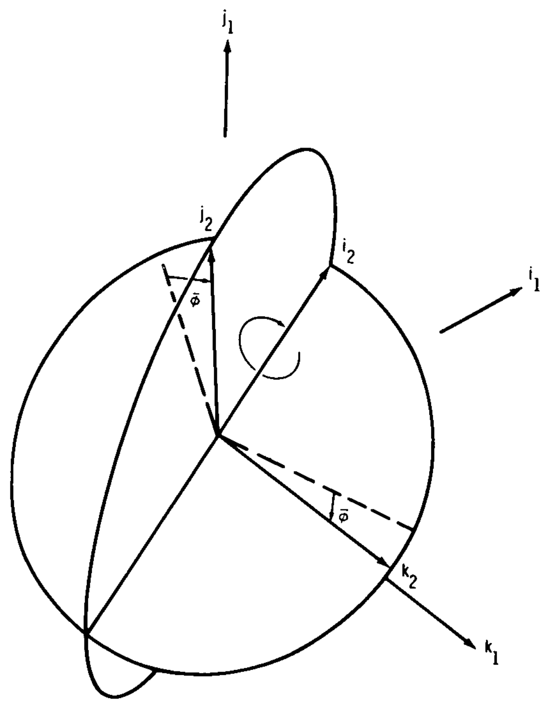
(a) Initial position.



(b) Pitch.



(c) Yaw.



(d) Roll.

Figure 4. - Order of rotation for the relative Euler angles.

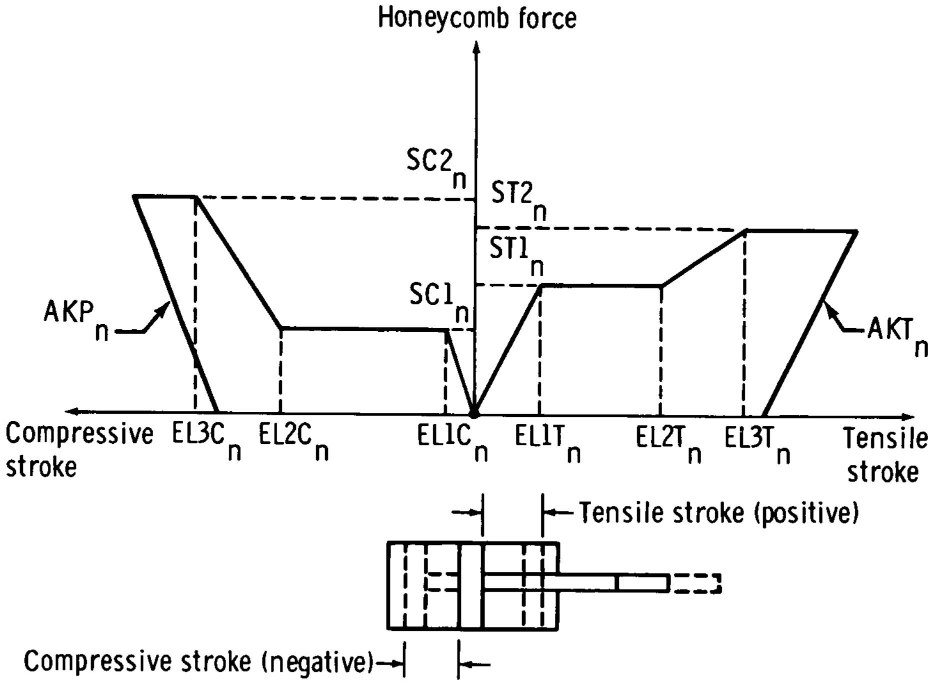


Figure 5. - Couch honeycomb-shock-strut characteristics.

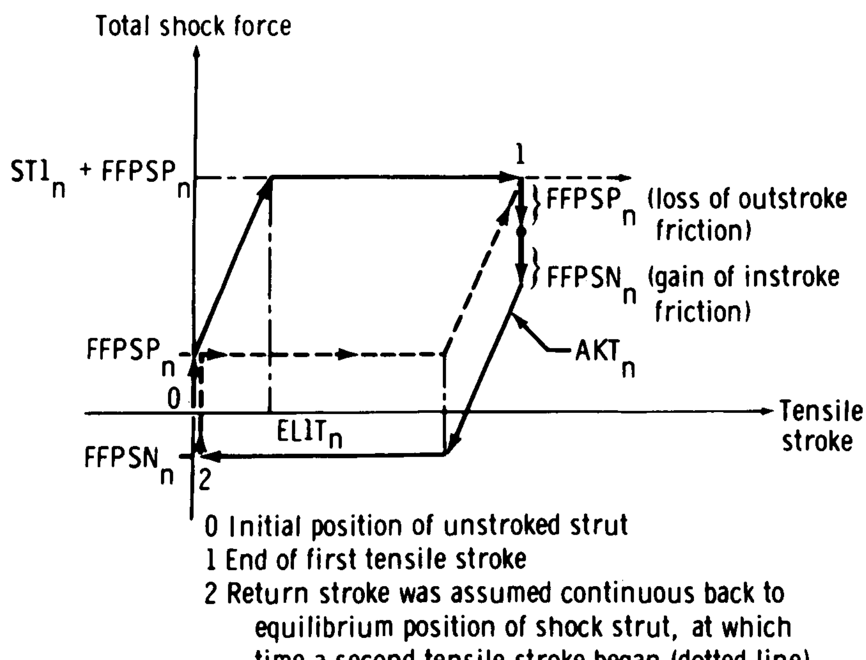


Figure 6. - Mechanism of friction and hysteresis in the honeycomb shock struts (tensile stroke used for example purposes).

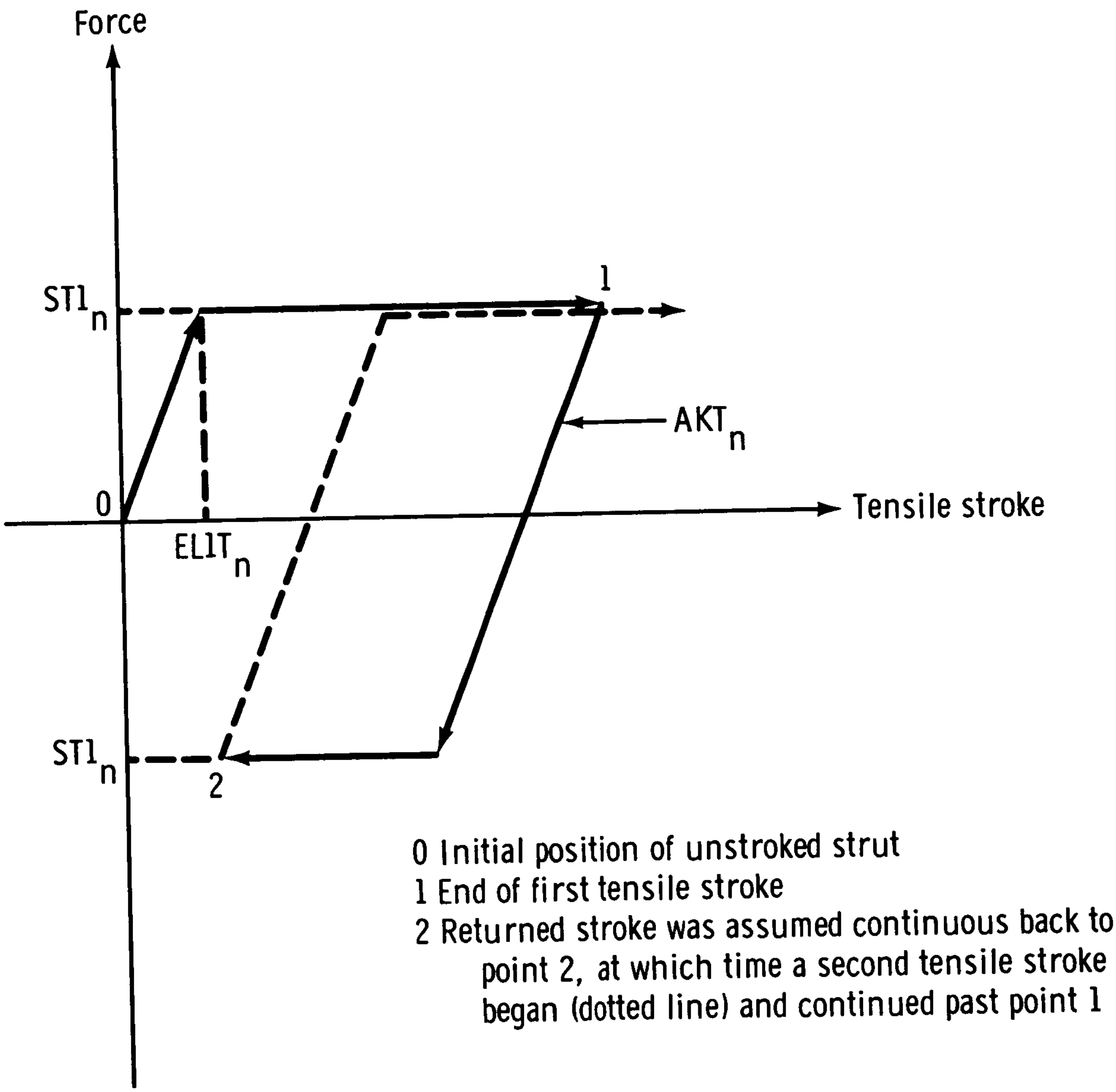


Figure 7. - Cyclic-deformation-shock-strut characteristics (tensile stroke used for example purposes).

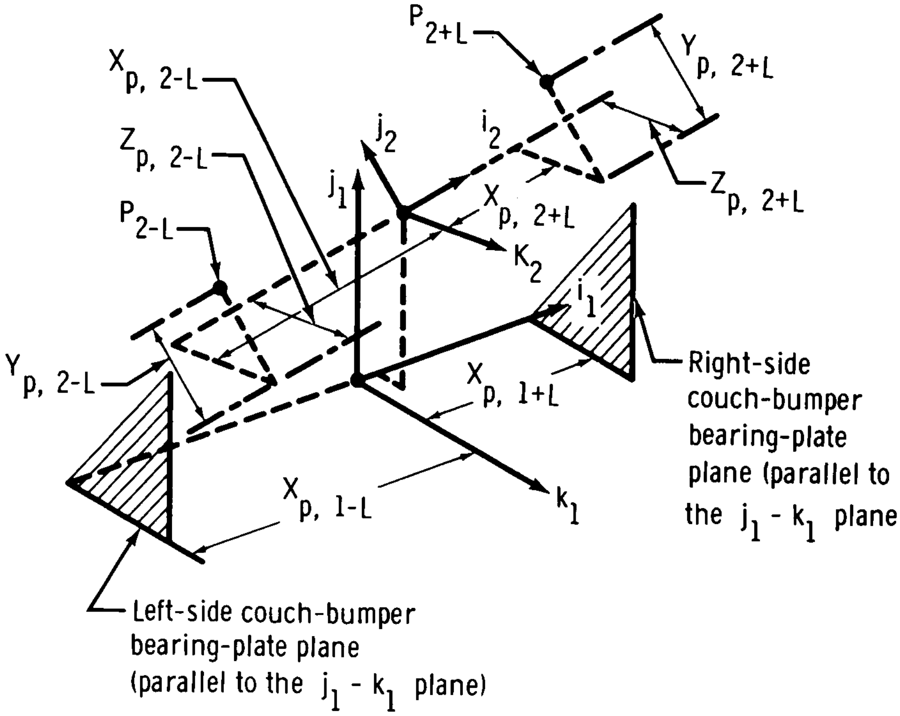


Figure 8. - Bumper-tip locations.

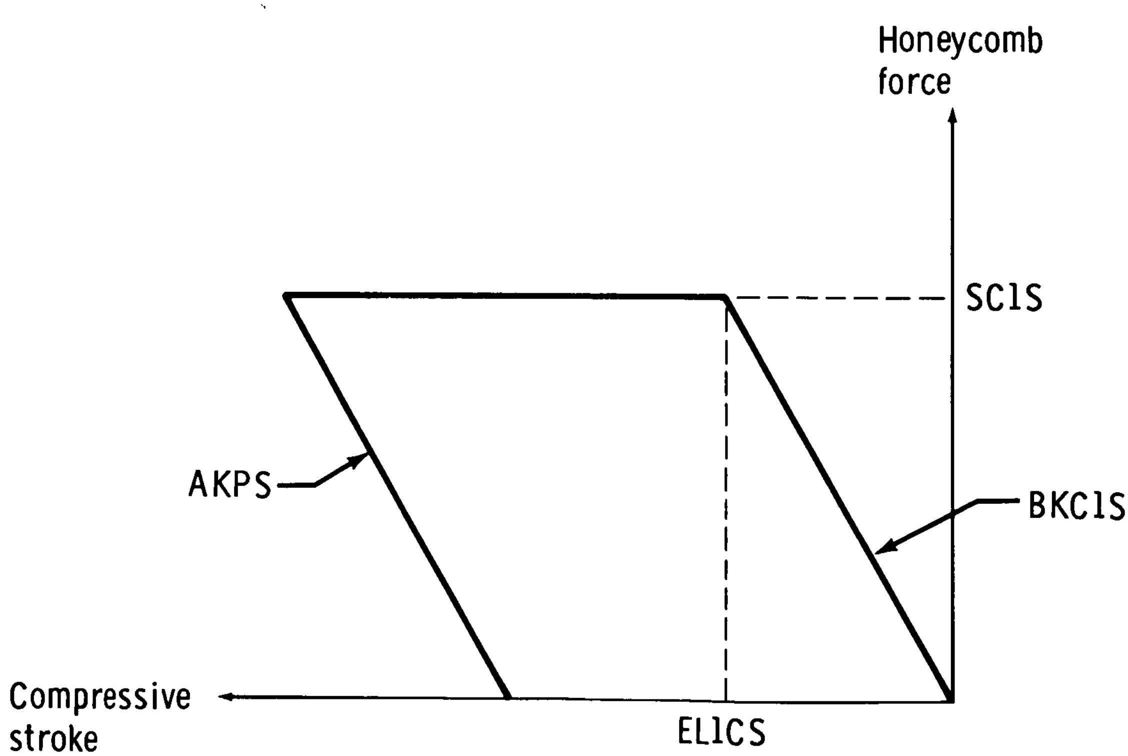


Figure 9. - Honeycomb-couch-bumper characteristics.

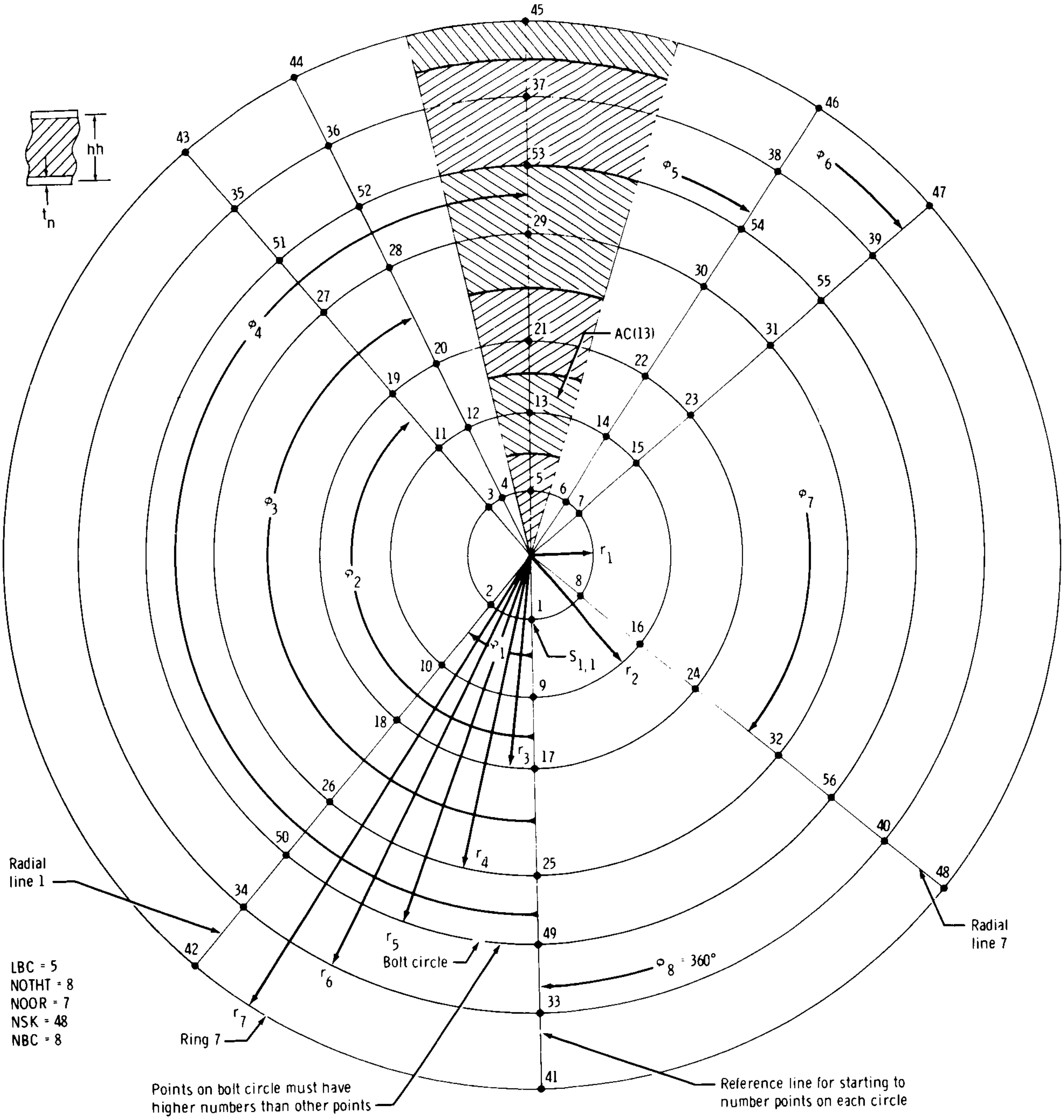


Figure 10. - Heat-shield-point locations; plate example (view from inside the command module).

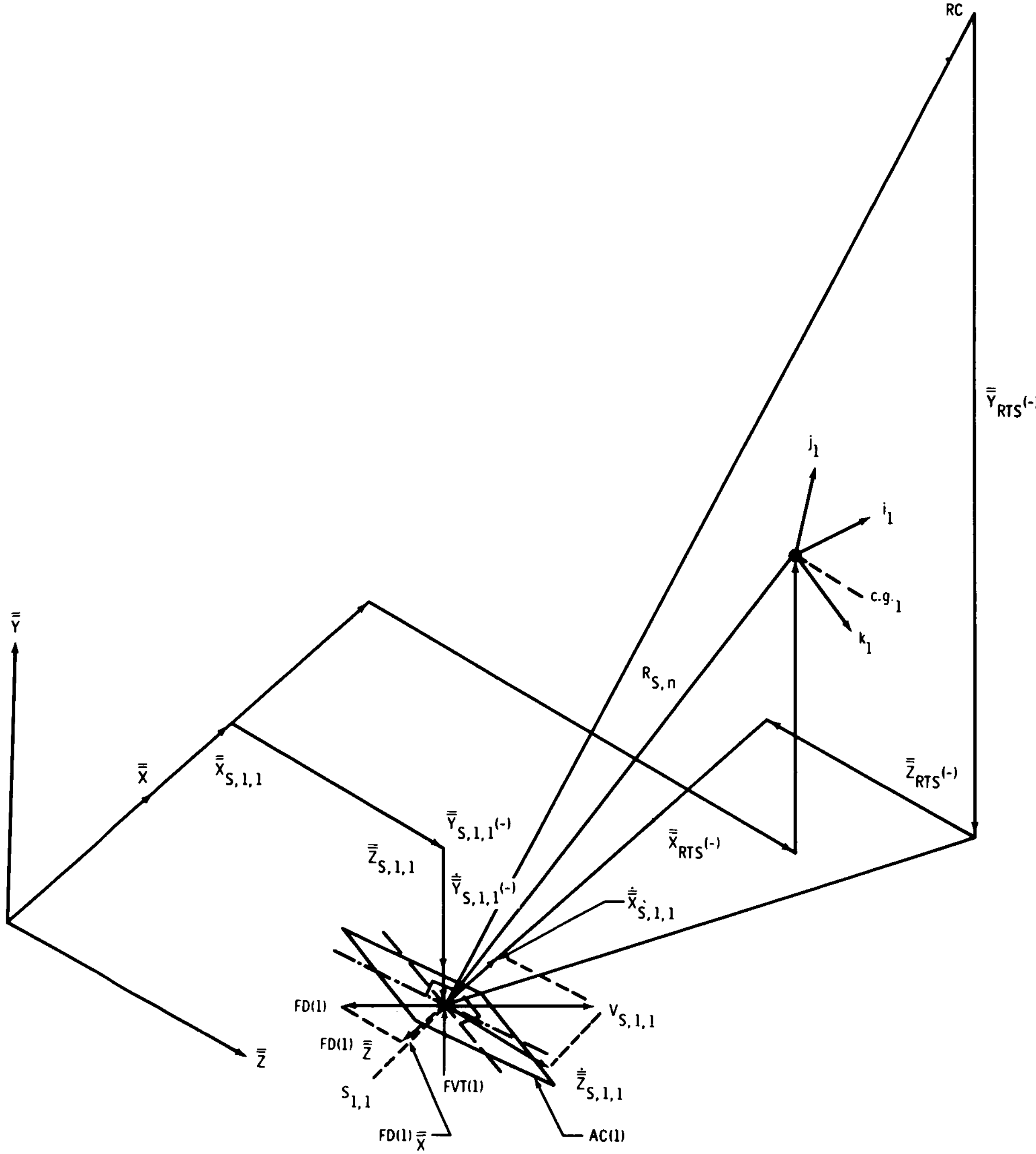
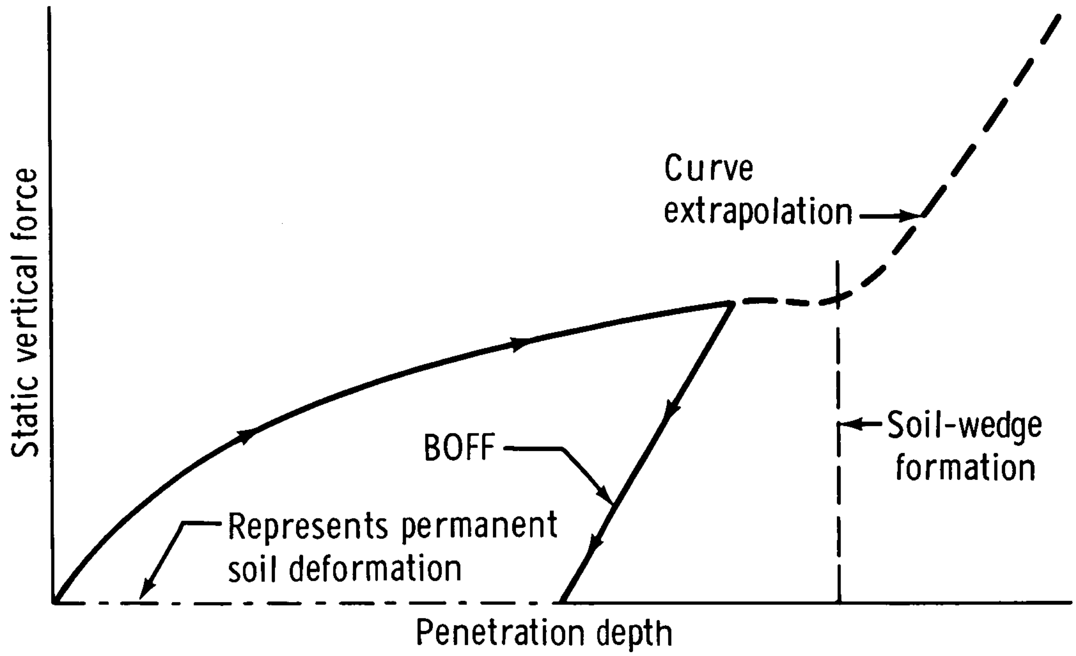
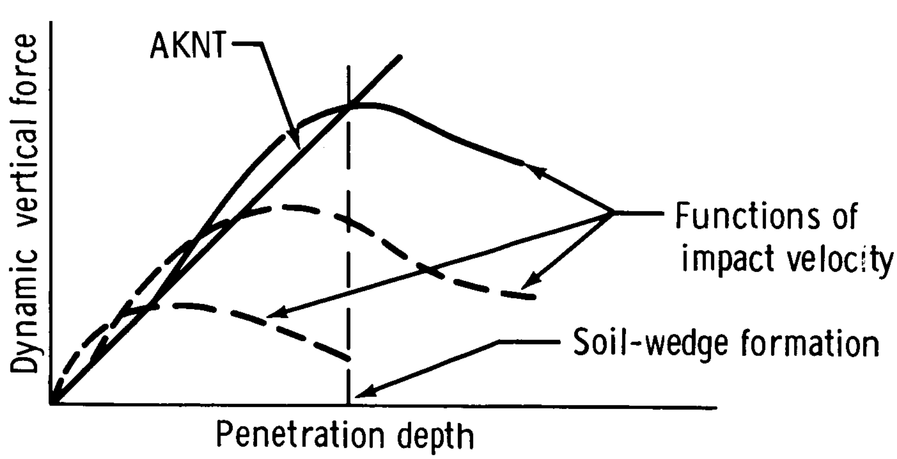


Figure 11. - Information required for the determination of ground forces.



(a) Static vertical force as a function of penetration depth.



(b) Dynamic vertical force as a function of penetration depth.

Figure 12. - Vertical soil-force characteristics.

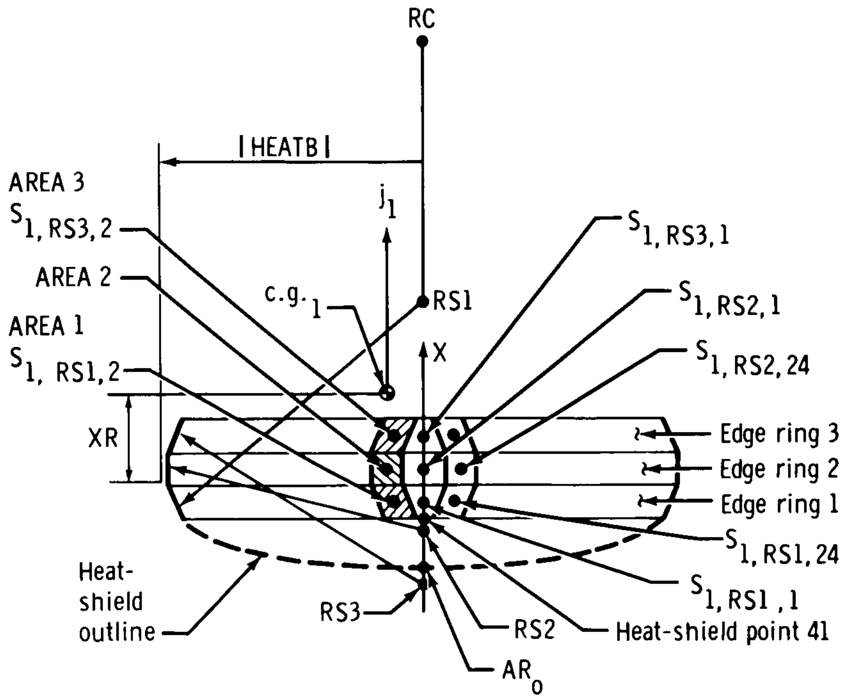


Figure 13. - Command module edge-ring geometry.

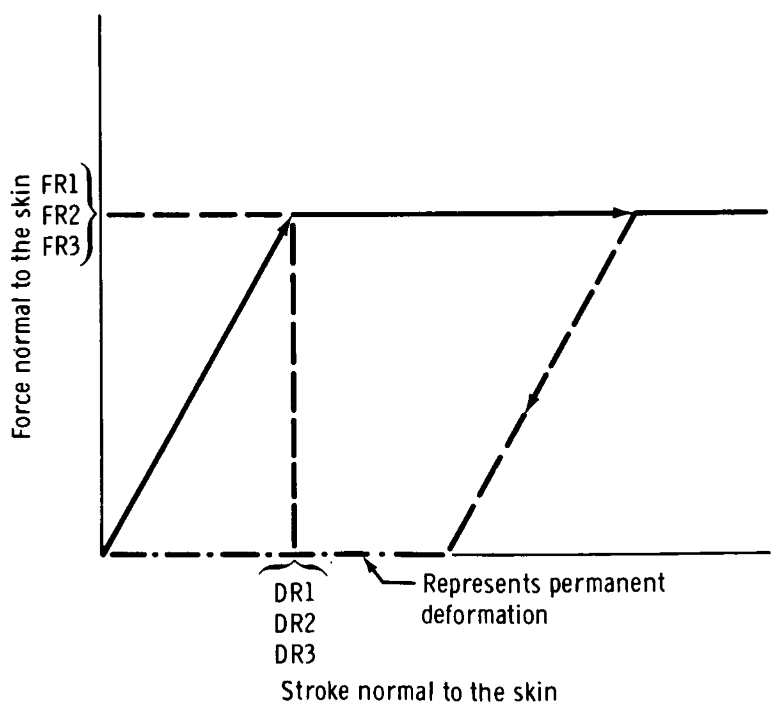
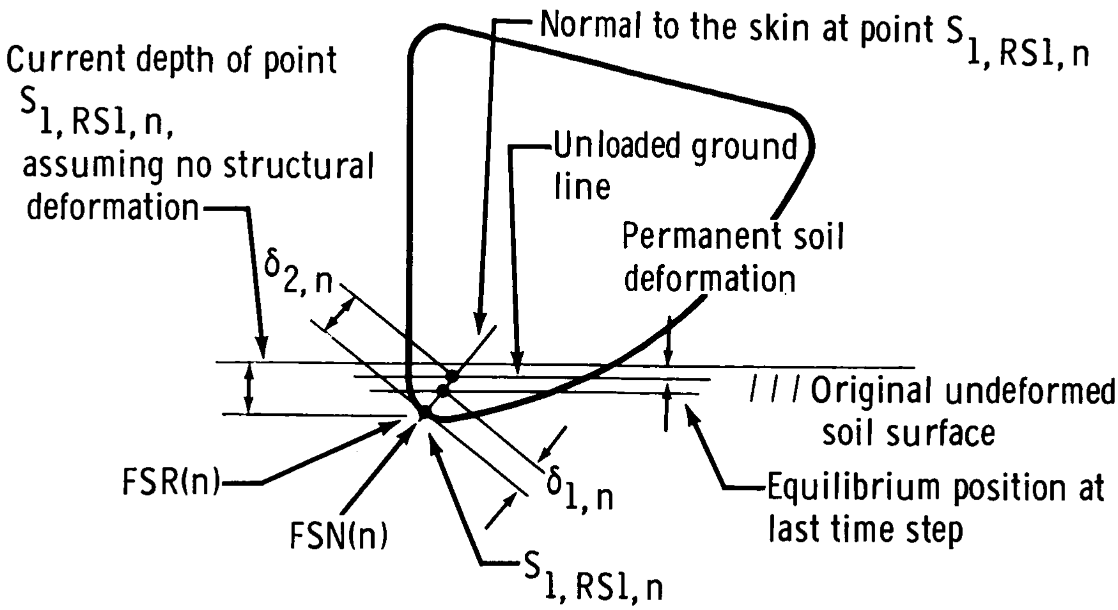
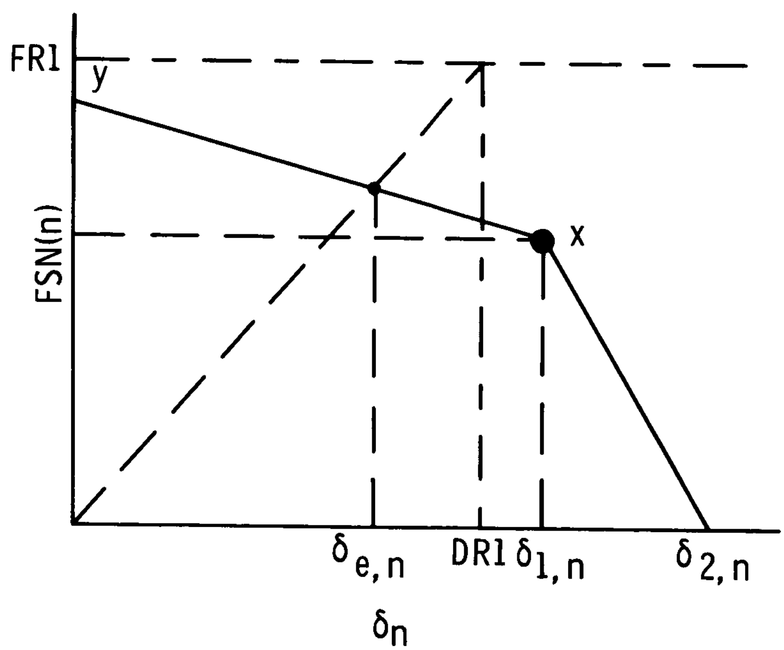


Figure 14. - Load-stroke curve for edge-ring points (same curve for each point in a given ring).



(a) Physical representation of equilibrium.



(b) Mathematical representation of equilibrium.

Figure 15. - Method of determining ground-structure equilibrium for a point on edge ring 1.

APPENDIX A

FORTRAN V PROGRAM FOR PREDICTING THE DYNAMIC RESPONSE OF THE APOLLO COMMAND MODULE TO EARTH IMPACT

EXPLANATION

As presented in this appendix, portions of the FORTRAN V program output require a high-speed microfilm recorder. If the recording equipment is unavailable, affected portions of the output may be bypassed by punching the appropriate number in position 7 on the first data card of each set. The computer program is capable of simulating impact cases involving certain CM hardware not used in the author's correlation study. Body 2, represented by a Weber couch, becomes a unitized couch when line 51 of subroutine INPUT is changed as indicated in line 50. To substitute honeycomb or linear springs for the arbitrarily specified cyclic-deformation shock struts, simply revise subroutine CABFOR per lines 74, 114, and 120.

COMPUTER PROGRAM LISTING

```
 SEG MAIN-(*B,*C)
B SEG SRC1-SRC2-SRC3-SRC4-SRC5-SRC6-SRC7-SRC8-SRC9-SRC10-SRC11-;
    SRC12-SRC13-SRC14-SRC15-SRC16-SRC17-SRC18-SRC19
C SEG SRFO
```

MAIN

```
      COMMON VAR,KNT,KFST,L
      DIMENSION VAR(9999),NTEGER(50),DYDX(100)
      EQUIVALENCE(VAR(301),NTEGER(1)),(NTEGER(32),NPP),(VAR(101),DYDX(1)
     1)
C  ZERO CORE AT INITIAL LOADING
      DO 30 J=1,9999
   30          VAR(J) = 0.0
C  SET DERIVATIVE OF INDEPENDENT VARIABLE WRT ITSELF EQUAL TO ONE
      DYDX(1)=1.0
   20 CALL RK
   10 IF(NTEGER(25))20,20,21
   21 CALL FILM(NPP)
      GO TO 20
      END
```

SRC1

```
              SUBROUTINE RK
      DIMENSION Y(100),DYDX(100),Q(100),D(100),P(9549),NTEGER(50)
     1,VAR(9999),T(1000)
      COMMON  VAR, KNT, KFST
      COMMON/ADM/T,NN,TMESH,KA1,A1,A2,A3,A4,A5,A7,MAP,SSE,YP,KPRNT
              EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(201),Q(
     1        1)),(VAR(301),NTEGER(1)),(VAR(351),D(1)),(VAR(451),P(1)),
     2(NTEGER(6),N),(NTEGER(32),NPP)
C             LOAD INPUT DATA INTO COMPUTER
              CALL INPUT
      A5=P(105)
      A7=P(106)
      A1=P(23)
      A2=P(24)
      A3=P(25)
      A4=P(104)
      KA1=NTEGER(9)
      NPP=0
      REWIND 9
      REWIND 11
      P(8)=-0.000001
      NTEGER(23)=0
      KNT=0
      KFST=0
      P(5964)=P(5966)*0.6
      P(5965)=P(5967)*0.6
   60 TMESH=P(1)
      NN=N-1
      NTEGER(22)=NN
      DO 30 J=1,NN
```

```
 30  T(J)=Y(J+1)
     T(NN+1)=Y(1)
     MAP=1
     CALL RKAM
     CALL HONSAV
 70  CALL OUTPUT
     IF(Y(1)-P(2))80,330,330
 80  CONTINUE
     CALL RKAM
     CALL HONSAV
     GO TO 70
330            RETURN
               END
```

SRC2

```
               SUBROUTINE INPUT
      DIMENSION YB2R10(24),FVR10(24),YB2R20(24),FVR20(24),YB2R30(24),
     1FVR30(24)
               DIMENSION Y(100),W(100)              ,P(9549),NTEGER(50 ),V
     1AR(9999),YB2S10(200),FVO(200)
     2,         THTSP(40),RSP(20),AC(200),ACR(19),ACTHT(40),DELEQO(72)
               COMMON VAR
               EQUIVALENCE (VAR(1),Y(1)),(VAR(201),W(1))
     1                   ,(VAR(301),NTEGER(1)),(VAR(451),P(1))
     2         ,(NTEGER(6),N),(NTEGER(2),NP),(NTEGER(5),NSK)
     3,(NTEGER(28),NPAR),(P(3158),YB2S10(1)),(P(2958),FVO(1)),(P(6000)
     4,ANG),(P(3967),FA),(P(3964),AKC)
     5,            (P(3970),AC(1)),(P(6501),THTSP(1)),(P(6541),RSP(1))
      EQUIVALENCE (P(6783),YB2R10(1)),(P(6855),FVR10(1)),(P(6807),
     1 YB2R20(1)),(P(6879),FVR20(1)),(P(6831),YB2R30(1)),
     2 (P(6903),FVR30(1)),(P(7303),DELEQO(1))
C              READ CONTROL INTEGERS INTO PROBLEM
               READ  (5,30)(NTEGER(J),J=1,9)
 30            FORMAT(9I5)
     WRITE (6,500)(NTEGER(J),J=1,9)
500  FORMAT(1H19I5)
     NTEGER(24)=NTEGER(6)
     NTEGER(6)=3*NTEGER(4)+25+NTEGER(3)
     NTEGER(29)=NTEGER(24)+1
     NTEGER(30)=NTEGER(29)+1
     NTEGER(21)=NTEGER(4) + 1
     NTEGER(25)=NTEGER(7)
     NTEGER(26)=NTEGER(8)
     REWIND 13
     DO 504 J=29,1307
     READ(13)IND,P(IND)
     WRITE(6,505)IND,P(IND)
505  FORMAT(I6,E20.8)
504  CONTINUE
     REWIND 13
C              CHECK FOR INDIVIDUAL FLOATING POINT DATA ENTRY
               IF(NP) 380,380,110
110            DO 140 J = 1,NP
               READ  (5,130)I, (P(I))
130            FORMAT(I5,E15.0)
     WRITE (6,150)I,P(I)
150  FORMAT(I6,E20.8)
```

```
  140           CONTINUE
      PHIR=P(112)*0.0175
      THEA=(-P(114))*0.01745
      STHEA=SIN(THEA)
      CTHEA=COS(THEA)
      TTHEA=STHEA/CTHEA
        XPRM=69.15*TTHEA
C FOR UNITIZED COUCH CHANGE 87.65 TO 84.35
      XDPRM=87.65*TTHEA
      XONE=(25.4+XDPRM)*STHEA
      XTWO=XDPRM/STHEA
      XTHR=(20.1+XPRM)*STHEA
      XFOU=XPRM/STHEA
      VTZ=P(110)*COS(PHIR)*(-12.0)
      XDBRQ=12.0*P(110)*SIN(PHIR)
      XTRA=P(111)*(-12.0)
      Z=0.01745
      COTH=COS(P(113)*Z)
      SITH=SIN(P(113)*Z)
      COPS=COS(P(115)*Z)
      SIPS=SIN(P(115)*Z)
      SIPH=SIN(P(114)*Z)
      COPH=COS(P(114)*Z)
      COM1=COPH*SIPS
      COM2=COPH*COPS
      P(110)=COTH*COPS*XDBRQ+COTH*SIPS*XTRA-SITH*VTZ
      P(111)=(SIPH*SITH*COPS-COM1)*XDBRQ+(SIPH*SITH*SIPS+COM2)*XTRA+
     1SIPH*COTH*VTZ
      P(112)=(SIPS*SIPH+COM2*SITH)*XDBRQ+(COM1*SITH-SIPH*COPS)*XTRA
     1+COPH*COTH*VTZ
      P(119)=P(110)
      P(120)=P(111)
      P(121)=P(112)
      P(123)=P(114)
      P(122)=P(113)
      P(124)=P(115)
      P(5993)=5.0+(20.1+XPRM)*CTHEA
      P(5996)=5.0+(25.4+XDPRM)*CTHEA
      P(5997)=XTWO-XONE-XFOU+XTHR
  380           CALL INAID
      WRITE(6,501)
  501 FORMAT(1H1)
C               ZERO THE Q AND SET IN IC
                DO 420 J = 1,N
                Q(J) = 0.0
  420           CONTINUE
C   SET HEAT SHIELD SKIN POINT COORDINATES INTO THEIR WORKING LOCATIONS (PUT IN
C       BODY 1 SYSTEM WITH ORIGIN AT C.G.1)
      DO 1 J=1,NSK
      P(J+1582)=P(J+982)+P(965)
      P(J+1782)=P(J+1182)+P(966)
      P(J+1982)=P(J+1382)+P(967)
    1 CONTINUE
C   SET RING SKIN POINT COORDINATES INTO THEIR WORKING LOCATIONS (PUT IN
C       BODY 1 SYSTEM WITH ORIGIN AT C.G.1)
      DO 50 J=1,72
      P(J+6563)=P(J+7014)+P(965)
      P(J+6635)=P(J+7086)+P(966)
      P(J+6707)=P(J+7158)+P(967)
   50 CONTINUE
      NPAR=NTEGER(4)-NTEGER(24)
      IF(NPAR)3,3,4
```

```
C   PUT HONEYCOMB SHOCK INITIAL CONDITIONS IN THEIR WORKING LOCATIONS
    4 DO 2 J=1,NPAR
      P(J+2483)=P(J+2423)
      P(J+2503)=P(J+2443)
      P(J+2523)=P(J+2463)
      P(J+2643)=P(J+2623)
    2 CONTINUE
      DO 5 J=1,NPAR
      P(J+2543)=P(J+2203)/P(J+2183)
      P(J+2563)=P(J+2243)/P(J+2223)
      P(J+2583)=(P(J+2263)-P(J+2203))/(P(J+2283)*P(J+2303))
      P(J+2603)=(P(J+2323)-P(J+2343))/(P(J+2343)*P(J+2363))
    5 CONTINUE
    3 CONTINUE
C   SIDE SHOCKS
      P(2751)=P(2747)
      P(2752)=P(2748)
      P(2753)=P(2749)
      P(2754)=P(2750)
C   CALCULATE YBAR COMPONENT OF POSITION VECTOR FROM CG1 TO RS1,RS2,RS3 IN I1,J1,
C        K1 SYSTEM
      P(6780)=P(5935)+P(966)
      P(6781)=P(5936)+P(966)
      P(6782)=P(5937)+P(966)
C   CALCULATE YBAR COMPONENT OF POSITION VECTOR FROM CG1 TO RC IN I1,J1,
C    K1 SYSTEM
      P(969)=P(968)+P(966)
C   SET SOIL PENETRATIONS AND FORCES TO ZERO.IF IT IS DESIRED TO INPUT
C    SOIL I.C.S OTHER THAN ZERO,THEY MUST BE SET TO WORKING VALUES HERE.
      DO 31 J=1,NSK
      YB2S10(J)=0.0
      FV0(J)=0.0
   31 CONTINUE
C   SET SOIL TO ZERO FOR RING 1
      DO 40 J=1,24
      YB2R10(J)=0.0
   40 FVR10(J)=0.0
C   SET SOIL TO ZERO FOR RING 2
      DO 41 J=1,24
      YB2R20(J)=0.0
   41 FVR20(J)=0.0
C   SET SOIL TO ZERO FOR RING 3
      DO 42 J=1,24
      YB2R30(J)=0.0
   42 FVR30(J)=0.0
C   SET RING DEFLECTIONS TO ZERO
      DO 503 J=1,72
  503 DELEQ0(J)=0.0
C   CALC.YBAR COMPONENT OF POS.VECTOR FROM CG1 TO RS1,RS2,RS3
      P(7375)=P(5935)+P(966)
      P(7376)=P(5936)+P(966)
      P(7377)=P(5937)+P(966)
      ANG=SIN(FA)/COS(FA)
      IF(AKC-0.001)6,6,7
    6 AKC=1.0+64.0*ANG**3
    7 CONTINUE
C   COMPUTE SOIL LOAD AREAS FOR EACH SKIN POINT(AC(1) THRU AC(NSK))
      LBC=P(5942)
      NOTHT=P(5941)
      NOOR=P(5940)
      NOTHTM=NOTHT-1
      NRADDU=NOOR-1
```

```
C   COMPUTE RADII BOUNDING THE AREAS
        DO 51 J=1,NRADDO
        IF(J.GT.(LBC-2))GO TO 52
        ACR(J)=((RSP(J+1)-RSP(J))/2.0)+RSP(J)
        GO TO 51
    52  IF(J.GT.(LBC-1))GO TO 53
        ACR(J)=((RSP(J+2)-RSP(J))/2.0)+RSP(J)
        GO TO 51
    53  IF(J.EQ.NRADDO)GO TO 54
        ACR(J)=((RSP(J+2)-RSP(J+1))/2.0)+RSP(J+1)
        GO TO 51
    54  ACR(J)=RSP(NOOR)
    51  CONTINUE
C   COMPUTE ANGLES BOUNDING THE AREAS
        ACTHT(1)= (THTSP(1)/2.0)+((THTSP(NOTHT)-THTSP(NOTHTM))/2.0)
        ACTHT(2)=THTSP(2)/2.0
        DO 55 J=3,NOTHT
        ACTHT(J)= (THTSP(J)-THTSP(J-2))/2.0
    55  CONTINUE
C   COMPUTE THE AREAS
C        INNER RING AREAS
        DO 56 J=1,NOTHT
    56  AC(J)= (0.0087266*ACR(1)**2)*ACTHT(J)
        NINDEX=NOTHT+1
        NAC=1
        NTIMES=NOOR-2
        DO 57 J=1,NTIMES
        M=0
        NEND=NINDEX+NOTHT-1
        DO 58 K=NINDEX,NEND
        M=M+1
    58  AC(K)=  0.0087266*ACTHT(M)*(ACR(NAC+1)**2-ACR(NAC)**2)
        NAC=NAC+1
        NINDEX=NINDEX+NOTHT
    57  CONTINUE
        ATOTAL=0.0
        DO 59 J=1,NSK
    59  ATOTAL=ATOTAL+AC(J)
        WRITE(6,60)ATOTAL
    60  FORMAT(35H TOTAL COMPUTED H.S.PROJECTED AREA=E15.8)
                  RETURN
                  END
```

SRC3

```
 SUBROUTINE HONSAV
 DIMENSION YB2R10(24),FVR10(24),YB2R20(24),FVR20(24),YB2R30(24),
1FVR30(24)
 DIMENSION YB2R1(24),YB2R2(24),YB2R3(24)
 DIMENSION P(9549),NTEGER(50),VAR(9999),CSUB3(20),NSTOR(20),CODE(20
1),YB2S1(200),YB2S10(200),FVO(200),FPR(200),XSTR(200),XB2RTS(200),
2YB2RTS(200),ZB2RTS(200),VECTB(200),AIN(200)
3,AC(200),Y(100)
 DIMENSION VECTBN(72),YB2RSN(72),XB2RSN(72),ZB2RSN(72),DELEQU(72),
1DELEQ0(72)
 COMMON VAR
 EQUIVALENCE (P(6783),YB2R10(1)),(P(6855),FVR10(1)),(P(6807),
1 YB2R20(1)),(P(6879),FVR20(1)),(P(6831),YB2R30(1)),
2 (P(6903),FVR30(1)),(P(7303),DELEQ0(1))
 EQUIVALENCE (P(6927),YB2R1(1)),(P(6951),YB2R2(1)),(P(6975),YB2R3
```

```
      1(1)),(P(7231),DELEQU(1)),(P(7303),DELEQO(1))
       EQUIVALENCE (P(7378),VECTBN(1)),(P(7450),YB2RSN(1)),(P(7522),
      1XB2RSN(1)),(P(7594),ZB2RSN(1))
       EQUIVALENCE(NTEGER(29),NSPSH),(NTEGER(30),INDI),(P(944),NSTOR(1))
      1,(P(401),CSUB3(1)),(P(661),COEE(1)),(NTEGER(21),NCABLE),
      2(NTEGER(28),NPAR),(VAR(301),NTEGER(1)),(VAR(451),P(1))
      3,(NTEGER(20),NLATP),(P(2751),SEVC3P),(P(459),STROKP),(P(2753),FEC
      413P),(NTEGER(19),NLATM),(P(2752),SEVC3M),(P(460),STROKM),(P(2754)
      5,FEC13M),(NTEGER(5),NSK),(P(2758),YB2S1(1)),(P(3158),YB2S10(1))
      6,(P(2958),FVO(1)),(P(3961),GCONST),(P(3962),GPOWER),(P(3358),FPR
      7(1)),(P(3558),XSTR(1)),(P(3758),VECTB(1)),(P(4180),XB2RTS(1)),
      8(P(4360),YB2RTS(1)),(P(4580),ZB2RTS(1))
      9,(P(3970),AC(1)),(VAR(1),Y(1))
       EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
      1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),AI1),(P(690),A2)
      2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
      36),G2),(P(697),H2),(P(698),AI2),(P(      4780),AIN(1))
       EQUIVALENCE (P(7669),YHSMX),(P(7670),NPHS),(P(7671),YR1MX),
      1(P(7672),NPR1),(P(7673),YR2MX),(P(7674),NPR2),(P(7675),YR3MX),
      2(P(7676),NPR3)
       IF(NPAR)5,5,6
     6 DO 4 J=INDI,NCABLE
       JJ=J-NSPSH
       IF(NSTOR(J))3,4,2
     2 P(JJ+2523)=COEE(J)
       P(JJ+2483)=CSUB3(J)
       GO TO 4
     3 P(JJ+2643)=COEE(J)
       P(JJ+2503)=CSUB3(J)
     4 CONTINUE
     5 CONTINUE
C   SAVE SIDE STRUT STROKES AND FORCES
       IF(NLATP)10,10,11
    10 SEVC3P=STROKP
       FEC13P=P(441)
       GO TO 11
    11 IF(NLATM)12,12,13
    12 SEVC3M=STROKM
       FEC13M=P(450)
    13 CONTINUE
C   SAVE GROUND FORCE AND PENETRATION DISTANCE
       YHSMX=0.0
       DO 15 J=1,NSK
       IF(YB2S1(J)-YB2S10(J))16,14,15
    16 YB2S10(J)=YB2S1(J)
       IF(YB2S10(J)+YHSMX)90,91,91
    90 YHSMX=-YB2S10(J)
       NPHS=J
    91 CONTINUE
       FVO(J)=(GCONST*(ABS(YB2S1(J)))**GPOWER)*AC(J)/11.0447
    15 CONTINUE
C   SAVE GROUND FORCE AND PENETRATION DISTANCE FOR RING 1
       YR1MX=0.0
       DO 64 J=1,24
       IF(YB2R1(J)-YB2R10(J))65,64,64
    65 YB2R10(J)=YB2R1(J)
       IF(YB2R10(J)+YR1MX)92,93,93
    92 YR1MX=-YB2R10(J)
       NPR1=J
    93 CONTINUE
       FVR10(J)=(GCONST*(ABS(YB2R1(J)))**GPOWER)*P(6561)/11.0447
    64 CONTINUE
```

```
C   SAVE GROUND FORCE AND PENETRATION DISTANCE FOR RING 2
      YR2MX=0.0
      DO 66 J=1,24
      IF(YB2R2(J)-YB2R20(J))67,67,66
   67 YB2R20(J)=YB2R2(J)
      IF(YB2R20(J)+YR2MX)94,95,95
   94 YR2MX=-YB2R20(J)
      NPR2=J
   95 CONTINUE
      FVR20(J)=(GCONST*(ABS(YB2R2(J)))**GPOWER)*P(6562)/11.0447
   66 CONTINUE
C   SAVE GROUND FORCE AND PENETRATION DISTANCE FOR RING 3
      YR3MX=0.0
      DO 68 J=1,24
      IF(YB2R3(J)-YB2R30(J))69,69,68
   69 YB2R30(J)=YB2R3(J)
      IF(YB2R30(J)+YR3MX)96,97,97
   96 YR3MX=-YB2R30(J)
      NPR3=J
   97 CONTINUE
      FVR30(J)=(GCONST*(ABS(YB2R3(J)))**GPOWER)*P(6563)/11.0447
   68 CONTINUE
C   SAVE RING DEFLECTIONS
      DO 71 J=1,72
      IF (DELEQU (J)-DELEQO(J))71,71,72
   72 DELEQO(J)=DELEQU(J)
      IF(J-24)73,73,74
   73 DELCK=P(7010)
      YFIX=P(7375)
      GO TO 77
   74 IF(J-48)75,75,76
   75 DELCK=P(7012)
      YFIX=P(7376)
      GO TO 77
   76 DELCK=P(7014)
      YFIX=P(7377)
   77 IF(DELEQU(J)-DELCK)71,71,78
   78 DELMOD=DELEQU(J)-DELCK
      WRITE(6,80)J,DELMOD
   80 FORMAT(9H EDGE PT.I4,16H HAS PERM.SET OFE15.8)
      DELEQO(J)=DELEQO(J)-DELMOD
C   MODIFY RING PT UNLOADED POSITION
      VECBN=VECTBN(J)-DELMOD
      THTON=ARCOS(ABS(YB2RSN(J))/VECTBN(J))
      STHTON=SIN(THTON)
      YB2AUX=VECBN*COS(THTON)
      YB2RNE=SIGN(YB2AUX,YB2RSN(J))
      RSUBN=VECBN*STHTON
      QSUBN=VECTBN(J)*STHTON
      XB2RNE=XB2RSN(J)*RSUBN/QSUBN
      ZB2RNE=ZB2RSN(J)*RSUBN/QSUBN
      SUB1NN=A1*XB2RNE+B1*YB2RNE+C1*ZB2RNE
      SUB2NN=D1*XB2RNE+E1*YB2RNE+F1*ZB2RNE
      SUB3NN=G1*XB2RNE+H1*YB2RNE+AI1*ZB2RNE
      P(J+6563)=SUB1NN+P(965)
      P(J+6635)=SUB2NN+YFIX
      P(J+6707)=SUB3NN+P(967)
   71 CONTINUE
C   DETERMINE PLATE DEFLECTIONS,XSTR(J),WHERE NEEDED
C   LET ALL LOADED POINTS HAVE PERMANENT SET EQUAL TO XSTR(J)
      REWIND 15
      KOUNT=0
```

```
      NLAST=0
      WRITE(6,1)
    1 FORMAT(1H )
      DO 18 J=1,NSK
C   DETERMINE WHICH POINTS ARE LOADED
      IF(ABS(FPR(J))-0.01)21,19,19
   19 IF(NLAST)22,22,23
   22 WRITE(6,24)J
   24 FORMAT(37H+LOWEST NO.PT.IN CONTACT WITH SOIL ISI4)
C   REPLACE THE FOLLOWING CARD WHEN STRUCTURAL MATRIX IS AVAILABLE.
   23 CONTINUE
      NLAST=J
      KOUNT=KOUNT+1
      GO TO 18
C   REPLACE THE FOLLOWING CARD WHEN STRUCTURAL MATRIX IS AVAILABLE.
   21 CONTINUE
   18 CONTINUE
      WRITE(6,25)KOUNT,NLAST
   25 FORMAT(1H+42X,39HTOTAL NO.OF PTS.IN CONTACT WITH SOIL ISI4,26H HIG
     1HEST NO.PT.IN CONTACT ISI4)
      WRITE(6,81)P(6999),P(7000),P(7001)
   81 FORMAT(27H EDGE RING FORCES I1,J1,K1=3E20.8)
      RETURN
      END
```

SRC4

```
SUBROUTINE INAID
DIMENSION Y(100),        P(9549) ,NTEGER(50 ),VAR(9999)
COMMON VAR
EQUIVALENCE (VAR(1),Y(1)),          (VAR(301),NTEGER(1)),(VA
R(451),P(1))
EQUIVALENCE (P(10),DL111),(P(11),DL112),(P(12),DL113),(P(
13),DL121),(P(14),DL122),(P(15),DL123),(P(16),DL131),(P(1
7),DL132),(P(18),DL133),(P(26),DL211),(P(27),DL212),(P(28
),DL213),(P(29),DL221),(P(30),DL222),(P(31),DL223),(P(32)
,DL231),(P(33),DL232),(P(34),DL233)
P(107)=DL111*P(970)+DL121*P(971)+DL131*P(972 )
P(108)=DL112*P(970)+DL122*P(971)+DL132*P(972)
P(109)= DL113*P(970)+DL123*P(971)+DL133*P(972)
P(116)=DL211*P(980)+DL221*P(981)+DL231*P(982)
P(117)=DL212*P(980)+DL222*P(981)+DL232*P(982)
P(118)=DL213*P(980)+DL223*P(981)+DL233*P(982)
SET IN INITIAL CONDITIONS
Y(1)=P(9)
                 Y(2)  = P(107)/57.2957795
                 Y(3)  = P(108)/57.2957795
                 Y(4)  = P(109)/57.2957795
                 Y(5)  = P(110)
                 Y(6)  = P(111)
                 Y(7)  = P(112)
                 Y(8)  = P(113)/57.2957795
                 Y(9)  = P(114)/57.2957795
                 Y(10) = P(115)/57.2957795
                 Y(11) = P(116)/57.2957795
                 Y(12) = P(117)/57.2957795
                 Y(13) = P(118)/57.2957795
                 Y(14) = P(119)
                 Y(15) = P(120)
                 Y(16) = P(121)
                 Y(17) = P(122)/57.2957795
```

```
                Y(18) = P(123)/57.2957795
                Y(19) = P(124)/57.2957795
      P(35)=SIN(     Y(8))
      P(36)=COS(     Y(8))
      P(38)=SIN(     Y(17))
      P(39)=COS(     Y(17))
      P(44)=SIN(     Y(9))
      P(45)=COS(     Y(9))
      P(46)=SIN(     Y(18))
      P(47)=COS(     Y(18))
      P(5976)=SIN(     Y(19))
      P(5977)=SIN(     Y(10))
      P(5978)=COS(     Y(19))
      P(5979)=COS(     Y(10))
      A2=P(39)*P(5978)
      B2=P(39)*P(5976)
      C2=-P(38)
      D2=P(46)*P(38)*P(5978)-P(5976)*P(47)
      E2=P(47)*P(5978)+P(46)*P(38)*P(5976)
      F2=P(46)*P(39)
      G2=P(5976)*P(46)+P(47)*P(38)*P(5978)
      H2=P(47)*P(38)*P(5976)-P(46)*P(5978)
      AI2=P(47)*P(39)
      A1=P(36)*P(5979)
      B1=P(36)*P(5977)
      C1=-P(35)
      D1=P(44)*P(35)*P(5979)-P(5977)*P(45)
      E1=P(45)*P(5979)+P(44)*P(35)*P(5977)
      F1=P(44)*P(36)
      G1=P(5977)*P(44)+P(45)*P(35)*P(5979)
      H1=P(45)*P(35)*P(5977)-P(44)*P(5979)
      AI1=P(45)*P(36)
      XXPR=A2*G1+B2*H1+C2*AI1
      AKKPR= D2*G1+E2*H1+F2*AI1
      ZZPR=G2*G1+H2*H1+AI2*AI1
         Y(20)=ATAN2((-XXPR),(SQRT(AKKPR**2+ZZPR**2)))
         Y(21)=ATAN2(AKKPR,ZZPR)
         Y(22)=ATAN2((A2*D1+B2*E1),(A2*A1+B2*B1+C2*C1))
         Y(23)=P(5992)
         Y(24)=P(5993)
         Y(25)=P(5994)
         Y(26)=P(5995)
         Y(27)=P(5996)
         Y(28)=P(5997)
C               SET IN CABLE INITIAL CONDITIONS
                NCABLE = NTEGER(21)
                NRESRV = NTEGER(3)
                NDO = 3*NCABLE
                DO 450 J = 1,NDO
                NPUT = J + 22 + NRESRV
  450               Y(NPUT) = P(J+139)
                RETURN
                END
```

SRC5

```
      SUBROUTINE DERFUN
                DIMENSION Y(100),DYDX(100),P(9549),NTEGER(50 ),VAR(9999),
    1           X1P1(20),Y1P1(20),Z1P1(20),X2P2(20),Y2P2(20),Z2P2(20),
    2           A1(20),A2(20),A3(20),FX11(20),FY11(20),FZ11(20),FX21(20),
    3           FY21(20),FZ21(20),GX1(20),GY1(20),GZ1(20),GX2(20),GY2(20)
```

```
C
     4          ,GZ2(20),XBR(20),YBR(20),ZBR(20),XBRD(20),YBRD(20),ZBRD(
     5          20),T(1000)
                COMMON VAR
      COMMON/ADM/T
                EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(301),
     1          NTEGER(1)),(VAR(461),P(1)),(Y(2),OMX1P),(DYDX(2),OMX1PD),
     2          (Y(3),OMY1P),(DYDX(3),OMY1PD),(Y(4),OMZ1P ),(Y(5),U1PP),
     3          (DYDX(5),U1PPD),(Y(6),V1PP),(DYDX(6),V1PPD),(Y(7),W1PP),
     4          (DYDX(7),W1PPD),(Y(8),THT1),(DYDX(8),THT1D),(Y(9),PHI1),
     5          (DYDX(9),PHI1D),(Y(10),PSI1),(DYDX(10),PSI1D),(Y(11),OMX2
     6          P),(DYDX(11),OMX2PD),(Y(12),OMY2P),(DYDX(12),OMY2PD),
     7          (Y(13),OMZ2P),(DYDX(13),OMZ2PD),(Y(14),U2PP),(DYDX(14),
     8          U2PPD),(Y(15),V2PP),(DYDX(15),V2PPD),(Y(16), W2PP),(DYDX
     9          (16),W2PPD),(Y(17),THT2),(DYDX(17),THT2D),(Y(18),PHI2)
                EQUIVALENCE (DYDX(18),PHI2D),(Y(19),PSI2),(DYDX(19),PSI2D
     1          ),(Y(20),THTBR),(DYDX(20),THTBRD),(Y(21),PHIBR),(DYDX(21)
     2          ,PHIBRD),(Y(22),PSIBR),(DYDX(22),PSIBRD),(P(3),CIXX1),
     3          (P(4),CIYY1),(P(5),CIZZ1),(P(6),CM1),(P(10),DL111),(P(11)
     4          ,DL112),(P(12),DL113),(P(13),DL121),(P(14),DL122),(P(15),
     5          DL123),(P(16),DL131),(P(17),DL132),(P(18),DL133),(P(19),
     6          CIXX2),(P(20),CIYY2),(P(21),CIZZ2),(P(22),CM2),(P(26),
     7          DL211),(P(27),DL212),(P(28),DL213),(P(29),DL221),(P(30),
     8          DL222),(P(31),DL223),(P(32),DL231),(P(33),DL232),(P(34),
     9          DL233),(P(35),STHT1),(P(36),CTHT1),(P(37),TTHT1)
                EQUIVALENCE (P(38),STHT2),(P(39),CTHT2),(P(40),TTHT2),
     1          (P(41),STHTBR),(P(42),CTHTBR),(P(43),TTHTBR),(P(44),SPHI1
     2          ),(P(45),CPHI1),(P(46),SPHI2),(P(47),CPHI2),(P(48),SPHIBR
     3          ),(P(49),CPHIBR),(P(50),GX1P),(P(51),GY1P),(P(52),GZ1P),(
     4          P(53),GX2P),(P(54),GY2P),(P(55),GZ2P),(P(56),OMX1),(P(57)
     5          ,OMY1),(P(58),OMZ1),(P(59),OMX2),(P(60),OMY2),(P(61),OMZ2
     6          ),(P(62),U1),(P(63),V1),(P(64),W1),(P(65),U2),(P(66),V2),
     7          (P(67),W2),(P(68),GAMB11),(P(69),GAMB12),(P(70),GAMB13),
     8          (P(71),GAMB21),(P(72),GAMB22),(P(73),GAMB23),(P(74),GAMB
     9          31),(P(75),GAMB32),(P(76),GAMB33),(P(77),SPSIBR)
                EQUIVALENCE (P(78),CPSIBR),(P(79),GX1T),(P(80),GY1T),(P(8
     1          1),GZ1T),(P(82),GX2T),(P(83),GY2T),(P(84),GZ2T),(P(85),
     2          FX11T),(P(86),FY11T),(P(87),FZ11T),(P(88),FX21T),(P(89),
     3          FY21T),(P(90),FZ21T),(P(91),GX1PT),(P(92),GY1PT),(P(93),
     4          GZ1PT),(P(94),GX2PT),(P(95),GY2PT),(P(96),GZ2PT),(P(97),
     5          SINPH2),(P(98),COSPH2),(P(99),COSTH2),(P(100),SINPH1),(P(
     6          101),COSPH1),(P(102),COSTH1),(P(221),X1P1(1)),(P(241),
     7          Y1P1(1)),(P(261),Z1P1(1)),(P(281),X2P2(1)),(P(301),Y2P2(1
     8          )),(P(321),Z2P2(1)),(P(341),A1(1)),(P(361),A2(1)),(P(381)
     9          ,A3(1)),(P(461),FX1I(1)),(P(481),FY1I(1))
                EQUIVALENCE (P(501),FZ1I(1)),(P(561),FZ2I(1)),(P(701),GX1
     1          (1)),(P(721),GY1(1)),(P(741),GZ1(1)),(P(761),GX2(1)),
     2          (P(781),GY2(1)),(P(801),GZ2(1)),(P(821),XBR(1)),(P(841),
     3          YBR(1)),(P(861),ZBR(1)),(P(881),XBRD(1)),(P(901),YBRD(1))
     4          ,(P(921),ZBRD(1)),(P(128),AGX1PT),(P(129),AGY1PT),(P(130)
     5          ,AGZ1PT),(P(131),AGX2PT),(P(132),AGY2PT),(P(133),AGZ2PT),
     6          (P(134),AFX11T),(P(135),AFY11T),(P(136),AFZ11T),(P(137),
     7          AFX21T),(P(138),AFY21T),(P(139),AFZ21T),(DYDX(4),
     8          OMZ1PD),(P(521),FX2I(1)),(P(541),FY2I(1))
      EQUIVALENCE(P(5976),SPSI2E),(P(5977),SPSI1E),(P(5978),CPSI2E),
C
     1(P(5979),CPSI1E),(NTEGER(9),KA1),(NTEGER(22),NN)
      IF(KA1-3)3,3,2
    3 DO 4 J=1,NN
    4 Y(J+1)=T(J)
      Y(1)=T(NN+1)
C               SET UP THE RELATIVE CONSTANT
    2           NCABLE = NTEGER(21)
                NRESRV = NTEGER(3)
```

```
C               SET IN X, Y, Z BAR VALUES WHICH RESULT FROM THE
C               INTEGRATION
                DO 12 J = 1,NCABLE
                JUMP1 = 3*J + 20 + NRESRV
                XBR(J) = Y(JUMP1)
                YBR(J) = Y(JUMP1 + 1)
   12           ZBR(J) = Y(JUMP1 + 2)
C               CALCULATE TRIGNOMETRIC FUNCTIONS
                STHT1 = SIN(THT1)
                CTHT1 = COS(THT1)
                TTHT1 = STHT1/CTHT1
                STHT2 = SIN(THT2)
                CTHT2 = COS(THT2)
                TTHT2 = STHT2/CTHT2
                STHTBR = SIN(THTBR)
                CTHTBR = COS(THTBR)
      CPSI1E=COS(PSI1)
      SPSI1E=SIN(PSI1)
      CPSI2E=COS(PSI2)
      SPSI2E=SIN(PSI2)
                TTHTBR = STHTBR/CTHTBR
                SPHI1 = SIN(PHI1)
                CPHI1 = COS(PHI1)
                SPHI2 = SIN(PHI2)
                CPHI2 = COS(PHI2)
                SPHIBR = SIN(PHIBR)
                CPHIBR = COS(PHIBR)
                SPSIBR = SIN(PSIBR)
                CPSIBR = COS(PSIBR)
C               CALCULATE GAMMA BAR VALUES FROM TRIG FUNCTIONS
                GAMB11 = CTHTBR*CPSIBR
                GAMB12 = CTHTBR*SPSIBR
                GAMB13 = -STHTBR
                GAMB21 = -CPHIBR*SPSIBR + SPHIBR*STHTBR*CPSIBR
                GAMB22 = CPHIBR*CPSIBR  + SPHIBR*STHTBR*SPSIBR
                GAMB23 = SPHIBR*CTHTBR
                GAMB31 = SPHIBR*SPSIBR  + CPHIBR*STHTBR*CPSIBR
                GAMB32 = -SPHIBR*CPSIBR + CPHIBR*STHTBR*SPSIBR
                GAMB33 = CPHIBR*CTHTBR
C               TRANSFORM PRINCIPAL AXIS ANGULAR VELOCITIES INTO SYMMETRY
C               AXIS COMPONENTS
                OMX1 = DL111*OMX1P + DL112*OMY1P + DL113*OMZ1P
                OMY1 = DL121*OMX1P + DL122*OMY1P + DL123*OMZ1P
                OMZ1 = DL131*OMX1P + DL132*OMY1P + DL133*OMZ1P
                OMX2 = DL211*OMX2P + DL212*OMY2P + DL213*OMZ2P
                OMY2 = DL221*OMX2P + DL222*OMY2P + DL223*OMZ2P
                OMZ2 = DL231*OMX2P + DL232*OMY2P + DL233*OMZ2P
      U1 = U1PP
      V1 = V1PP
      W1 = W1PP
      U2 = U2PP
      V2 = V2PP
      W2 = W2PP
      OMX1PP=OMX1*GAMB11+OMY1*GAMB12-OMZ1*STHTBR
      OMY1PP=OMX1*GAMB21+OMY1*GAMB22+OMZ1*GAMB23
      OMZ1PP=OMX1*GAMB31+OMY1*GAMB32+OMZ1*GAMB33
C               CALCULATE THETA, PHI, PSI BAR DERIVATIVES
      THTBRD=CPHIBR*(OMY2-OMY1PP)-SPHIBR*(OMZ2-OMZ1PP)
      PHIBRD=OMX2-OMX1PP+TTHTBR*SPHIBR*(OMY2-OMY1PP)+TTHTBR*CPHIBR*
     1(OMZ2-OMZ1PP)
      PSIBRD=SPHIBR*(OMY2-OMY1PP)/CTHTBR+CPHIBR*(OMZ2-OMZ1PP)/CTHTBR
C               CALCULATE THT, PHI, PSI DERIVATIVES
                THT1D = CPHI1*OMY1 - SPHI1*OMZ1
                PHI1D = OMX1 + TTHT1*(SPHI1*OMY1 + CPHI1*OMZ1)
```

```
                 PSI1D = (SPHI1*OMY1 + CPHI1*OMZ1)/CTHT1
                 THT2D = CPHI2*OMY2 - SPHI2*OMZ2
                 PHI2D = OMX2 + TTHT2*(SPHI2*OMY2 + CPHI2*OMZ2)
                 PSI2D = (SPHI2*OMY2 + CPHI2*OMZ2)/CTHT2
C                NOW CALCULATE THE ALPHA VALUES
                 DO 620 J = 1,NCABLE
                 A1(J) = U2 + Z2P2(J)*OMY2 - Y2P2(J)*OMZ2
                 A2(J) = V2 + X2P2(J)*OMZ2 - Z2P2(J)*OMX2
                 A3(J) = W2 + Y2P2(J)*OMX2 - X2P2(J)*OMY2
C                THEN CALCULATE X, Y, Z BAR DERIVATIVES FOR EACH
C                ATTACHMENT POINT
                 XBRD(J) = YBR(J)*OMZ1 - ZBR(J)*OMY1 - U1
     1           - Z1P1(J)*OMY1 + Y1P1(J)*OMZ1
     2           +GAMB11*A1(J)+GAMB21*A2(J)+GAMB31*A3(J)
                 YBRD(J) = ZBR(J)*OMX1 - XBR(J)*OMZ1 - V1
     1           - X1P1(J)*OMZ1 + Z1P1(J)*OMX1
     2           + GAMB12*A1(J) + GAMB22*A2(J) + GAMB32*A3(J)
  620            ZBRD(J) = XBR(J)*OMY1 - YBR(J)*OMX1 - W1
     1           - Y1P1(J)*OMX1 + X1P1(J)*OMY1
     2           + GAMB13*A1(J) + GAMB23*A2(J) + GAMB33*A3(J)
C   TRANSFER TO THE SHOCK FORCE SUBROUTINE
      CALL CABFOR
C                TRANSFORM SYMMETRY AXIS FORCES IN BODY 1 INTO SYMMETRY
C                AXIS FORCES IN BODY 2
                 DO 790 J = 1,NCABLE
                 FX2I(J) = - GAMB11*FX1I(J) - GAMB12*FY1I(J)
     1           - GAMB13*FZ1I(J)
                 FY2I(J) = - GAMB21*FX1I(J) - GAMB22*FY1I(J)
     1           - GAMB23*FZ1I(J)
                 FZ2I(J) = - GAMB31*FX1I(J) - GAMB32*FY1I(J)
     1           - GAMB33*FZ1I(J)
C                CALCULATE SYMMETRY AXIS MOMENTS ON BOTH BODIES
      GX1(J) = Y1P1 (J)*FZ1I(J) - Z1P1 (J)*FY1I(J)
      GY1(J)= Z1P1 (J)*FX1I(J) - X1P1 (J)*FZ1I(J)
      GZ1(J)= X1P1 (J)*FY1I(J) - Y1P1 (J)*FX1I(J)
      GX2(J)= Y2P2 (J)*FZ2I(J) - Z2P2 (J)*FY2I(J)
      GY2(J)= Z2P2 (J)*FX2I(J) - X2P2 (J)*FZ2I(J)
  790 GZ2(J) = X2P2 (J)*FY2I(J) - Y2P2 (J)*FX2I(J)
C  TRANSFER TO LATERAL SHOCK SUBROUTINE
      CALL SIDSHK
      CALL GROFOR
      CALL RINGF
C                NOW SUM THE SYMMETRY AXIS COMPONENTS OF MOMENT
      GX1T=P(445)+P(454)+P(4177)+P(7002)
      GY1T=P(446)+P(455)+P(4178)+P(7003)
      GZ1T=P(447)+P(456)+P(4179)+P(7004)
                 GX2T = 0.0
      GY2T=P(448)+P(457)
      GZ2T=P(449)+P(458)
                 DO 920 J = 1,NCABLE
                 GX1T = GX1T + GX1(J)
                 GY1T = GY1T + GY1(J)
                 GZ1T = GZ1T + GZ1(J)
                 GX2T = GX2T + GX2(J)
                 GY2T = GY2T + GY2(J)
  920            GZ2T = GZ2T + GZ2(J)
C                NEXT, SUM THE SYMMETRY AXIS COMPONENTS OF FORCE
      FX1IT=P(442)+P(451)+P(4174)+P(6999)
      FY1IT=P(443)+P(452)+P(4175)+P(7000)
      FZ1IT=P(444)+P(453)+P(4176)+P(7001)
      FX2IT=P(441)+P(450)
                 FY2IT = 0.0
                 FZ2IT = 0.0
```

```
                DO 1050 J = 1,NCABLE
                FX1IT = FX1IT + FX1I(J)
                FY1IT = FY1IT + FY1I(J)
                FZ1IT = FZ1IT + FZ1I(J)
                FX2IT = FX2IT + FX2I(J)
                FY2IT = FY2IT + FY2I(J)
 1050           FZ2IT = FZ2IT + FZ2I(J)
C               TRANSFORM SYMMETRY AXIS COMPONENTS OF TOTAL MOMENT INTO
C               PRINCIPAL AXIS COMPONENTS
                GX1PT = DL111*GX1T + DL121*GY1T + DL131*GZ1T
                GY1PT = DL112*GX1T + DL122*GY1T + DL132*GZ1T
                GZ1PT = DL113*GX1T + DL123*GY1T + DL133*GZ1T
                GX2PT = DL211*GX2T + DL221*GY2T + DL231*GZ2T
                GY2PT = DL212*GX2T + DL222*GY2T + DL232*GZ2T
                GZ2PT = DL213*GX2T + DL223*GY2T + DL233*GZ2T
C         CALL FORCING FUNCTION AND GRAVITY SUBROUTINE
          CALL FORFUN
C               CALCULATE THE ANGULAR VELOCITY DERIVATIVES
                OMX1PD = (GX1PT + OMY1P*OMZ1P*(CIYY1-CIZZ1))/CIXX1
     1          + AGX1PT/CIXX1
                OMY1PD = (GY1PT + OMX1P*OMZ1P*(CIZZ1-CIXX1))/CIYY1
     1          + AGY1PT/CIYY1
                OMZ1PD = (GZ1PT + OMX1P*OMY1P*(CIXX1-CIYY1))/CIZZ1
     1          + AGZ1PT/CIZZ1
                OMX2PD = (GX2PT + OMY2P*OMZ2P*(CIYY2-CIZZ2))/CIXX2
     1          + AGX2PT/CIXX2
                OMY2PD = (GY2PT + OMX2P*OMZ2P*(CIZZ2-CIXX2))/CIYY2
     1          + AGY2PT/CIYY2
                OMZ2PD = (GZ2PT + OMX2P*OMY2P*(CIXX2-CIYY2))/CIZZ2
     1          + AGZ2PT/CIZZ2
C               CALCULATE BODY AXIS VELOCITY RATES
                U1PPD = - OMY1*W1PP + OMZ1*V1PP + FX1IT/CM1
     1          + AFX1IT/CM1
                V1PPD = - OMZ1*U1PP + OMX1*W1PP + FY1IT/CM1
C
     1          + AFY1IT/CM1
                W1PPD = - OMX1*V1PP + OMY1*U1PP + FZ1IT/CM1
     1          + AFZ1IT/CM1
                U2PPD = - OMY2*W2PP + OMZ2*V2PP + FX2IT/CM2
     1          + AFX2IT/CM2
                V2PPD = - OMZ2*U2PP + OMX2*W2PP + FY2IT/CM2
     1          + AFY2IT/CM2
                W2PPD = - OMX2*V2PP + OMY2*U2PP + FZ2IT/CM2
     1          + AFZ2IT/CM2
C               SET IN RATES OF CHANGE OF COORDINATES AS DYDXS
                DO 1280 J = 1,NCABLE
                JUMP2 = 3*J + 20 + NRESRV
                DYDX(JUMP2)      = XBRD(J)
                DYDX(JUMP2 + 1) = YBRD(J)
 1280           DYDX(JUMP2 + 2) = ZBRD(J)
          DYDX(23)= P(681)*U1PP+P(684)*V1PP+P(687)*W1PP
          DYDX(24)= P(682)*U1PP+P(685)*V1PP+P(688)*W1PP
          DYDX(25)= P(683)*U1PP+P(686)*V1PP+P(689)*W1PP
          DYDX(26)= P(690)*U2PP+P(693)*V2PP+P(696)*W2PP
          DYDX(27)= P(691)*U2PP+P(694)*V2PP+P(697)*W2PP
          DYDX(28)= P(692)*U2PP+P(695)*V2PP+P(698)*W2PP
          IF(KA1-3)5,5,6
        5 NNN=NN+1
          DO 7 J=2,NNN
          JJJ=NN+J
        7 T(JJJ)=DYDX(J)
        6 CONTINUE
                RETURN
                END
```

SRC6

```
      SUBROUTINE CABFOR
      DIMENSION P(9549),NTEGER(50 ),VAR(9999),FX11(20),FY11(20)
     1,FZ11(20),XBR(20),ZBR(20),XBRD(20),YBRD(20),ZBRD(20),
     2CABLE(20),SPRK(20),CDAMP(20),RP1P2(20),FORS(20),COEE(20)
     3,YBR(20),CSUB1(20),CSUB2(20),CSUB3(20),NSTOR(20)
      COMMON VAR
      EQUIVALENCE (VAR(301),NTEGER(1)),(VAR(451),P(1)),(P(461),
     1FX11(1)),(P(481),FY11(1)),(P(501),FZ11(1)),(P(821),XBR(1)
     2),(P(841),YBR(1)),(P(861),ZBR(1)),(P(881),XBRD(1)),(P(901
     3),YBRD(1)),(P(921),ZBRD(1)),(P(601 ),SPRK(1)),(P(621 ),
     4CDAMP(1)),(P(641 ),RP1P2(1)),(P(201 ),FORS (1)),(P(661 ),
     5COEE(1)),(P(581 ),CABLE(1))
 EQUIVALENCE(NTEGER(29),NSPSH),(NTEGER(30),INDI),(P(944),NSTOR(1))
    1,(P(401),CSUB3(1))
     EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
    1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),A11),(P(690),A2)
    2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
    36),G2),(P(697),H2),(P(698),A12)
      A1=P(36)*P(5979)
      B1=P(36)*P(5977)
      C1=-P(35)
      D1=P(44)*P(35)*P(5979)-P(5977)*P(45)
      E1=P(45)*P(5979)+P(44)*P(35)*P(5977)
      F1=P(44)*P(36)
      G1=P(5977)*P(44)+P(45)*P(35)*P(5979)
      H1=P(45)*P(35)*P(5977)-P(44)*P(5979)
      A11=P(45)*P(36)
      A2=P(39)*P(5978)
      B2=P(39)*P(5976)
      C2=-P(38)
      D2=P(46)*P(38)*P(5978)-P(5976)*P(47)
      E2=P(47)*P(5978)+P(46)*P(38)*P(5976)
      F2=P(46)*P(39)
      G2=P(5976)*P(46)+P(47)*P(38)*P(5978)
      H2=P(47)*P(38)*P(5976)-P(46)*P(5978)
      A12=P(47)*P(39)
              NCABLE = NTEGER(21)
     IF(NTEGER(24))1,1,2
C   COMPUTE INSTANTANEOUS SPRING SHOCK LENGTH
    2         DO 180 J = 2,NSPSH
              RP1P2(J) = SQRT(XBR(J)**2 + YBR(J)**2 + ZBR(J)**2)
      CSUB1(J)=(XBR(J)*XBRD(J)+YBR(J)*YBRD(J)+ZBR(J)*ZBRD(J))/RP1P2(J)
      CSUB3(J)=RP1P2(J)-CABLE(J)
      COEE(J)=SPRK(J)*  CSUB3(J)         +CDAMP(J)*CSUB1(J)*ABS(CSUB1
     2(J))
      CSUB2(J)=COEE(J)/RP1P2(J)
              FX11(J) =CSUB2(J)*XBR(J)
              FY11(J) =CSUB2(J)*YBR(J)
              FZ11(J) =CSUB2(J)*ZBR(J)
  180         CONTINUE
     FCABMX=0.0
     SCABMX=0.0
     DO 302 J=2,NSPSH
     IF(ABS(COEE(J))-FCABMX)300,300,301
 301 FCABMX=COEE(J)
     AAA=J
 300 IF(ABS(CSUB3(J))-SCABMX)302,302,303
 303 SCABMX=CSUB3(J)
     BBB=J
```

```
302 CONTINUE
    P(200)=FCABMX
    P(699)=SCABMX
    P(700)=BBB
    P(5998)=AAA
  1  FXII(1)=0.0
    FYII(1)=0.0
    FZII(1)=0.0
    RP1P2(1)=SQRT(XBR(1)**2+YBR(1)**2+ZBR(1)**2)
    IF(NTEGER(28))3,3,4
  4 DO 5 J=INDI,NCABLE
    JJ=J-NSPSH
    RP1P2(J)=SQRT(XBR(J)**2+YBR(J)**2+ZBR(J)**2)
    CSUB1(J)=(XBR(J)*XBRD(J)+YBR(J)*YBRD(J)+ZBR(J)*ZBRD(J))/RP1P2(J)
C   FOR HONEYCOMB STRUTS,CHANGE THE FOLLOWING STATEMENT TO
C       RAMDMP=0.
        RAMDMP=P(622)*CSUB1(J)
        CSUB3(J)=RP1P2(J)-CABLE(J)
    6 IF(CSUB3(J))7,7,8
    8 IF(CSUB3(J)-P(JJ+2483))9,9,10
   10 IF(CSUB3(J)-P(JJ+2183))11,11,12
   11 COEE(J)=P(JJ+2543)*CSUB3(J)
      NSTOR(J)=1
      GO TO 26
   12 IF(CSUB3(J)-P(JJ+2303))13,13,14
   13 COEE(J)= P(JJ+2203)
      NSTOR(J)=1
      GO TO 26
   14 IF(CSUB3(J)-P(JJ+2283))15,15,16
   15 COEE(J)=P(JJ+2583)*(CSUB3(J)-P(JJ+2303))+P(JJ+2203)
      NSTOR(J)=1
      GO TO 26
   16 COEE(J)=P(JJ+2263)
      NSTOR(J)=1
      GO TO 26
    7 IF(-CSUB3(J)+P(JJ+2503))17,17,18
   18 IF(-CSUB3(J)-P(JJ+2223))19,19,20
   19 COEE(J)=P(JJ+2563)*CSUB3(J)
      NSTOR(J)=-1
      GO TO 26
   20 IF(-CSUB3(J)-P(JJ+2363))21,21,22
   21 COEE(J)=-P(JJ+2243)
      NSTOR(J)=-1
      GO TO 26
   22 IF(-CSUB3(J)-P(JJ+2343))23,23,24
   23 COEE(J)=(CSUB3(J)+P(JJ+2363))*P(JJ+2603)-P(JJ+2243)
      NSTOR(J)=-1
      GO TO 26
   24 COEE(J)=-P(JJ+2323)
      NSTOR(J)=-1
      GO TO 26
    9 COEE(J)=P(JJ+2523)-P(JJ+2343)*(P(JJ+2483)-CSUB3(J))+RAMDMP
      NSTOR(J)=0
      IF(COEE(J))25,25,26
C   FOR HONEYCOMB STRUTS,CHANGE THE FOLLOWING STATEMENT TO
C   25 COEE(J)=0.
    25 IF(COEE(J).LT.(-P(JJ+2203)))COEE(J)=-P(JJ+2203)
       GO TO 26
    17 COEE(J)=P(JJ+2643)-P(JJ+2463)*(P(JJ+2503)-CSUB3(J))+RAMDMP
       NSTOR(J)=0
C   FOR HONEYCOMB STRUTS,CHANGE THE FOLLOWING STATEMENT TO
C       IF(COEE(J))26,26,25
```

```
C    AND REMOVE STATEMENT NUMBER 410
        IF(COEE(J))26,26,410
  410 IF(COEE(J).GT.P(JJ+2243))COEE(J)=P(JJ+2243)
C   COMPUTE HONEYCOMB SHOCK FRICTION FORCE
   26 IF(CSUB3(J))305,305,306
  305 IF(CSUB1(J))307,308,309
  307 FRICF=-P(JJ+2683)
      GO TO 310
  308 FRICF=0.0
      GO TO 310
  309 FRICF=P(JJ+2663)
      GO TO 310
  306 IF(CSUB1(J))311,308,313
  311 FRICF=-P(JJ+2723)
      GO TO 310
  313 FRICF=P(JJ+2703)
C MODIFY FRICTION FORCE FOR LOW STRUT VELOCITY IF NECESSARY
  310 STVABS=ABS(CSUB1(J))
      IF(STVABS-1.2)400,400,401
  400 FBU=SQRT(STVABS/1.2)
      GO TO 402
  401 FBU=1.0
  402 FRICF=FBU*FRICF
      FORS(J)=COEE(J)+FRICF
      CSUB2(J)=FORS(J)/RP1P2(J)
      FX11(J)=CSUB2(J)*XBR(J)
      FY11(J)=CSUB2(J)*YBR(J)
      FZ11(J)=CSUB2(J)*ZBR(J)
    5 CONTINUE
      FCABNX=0.0
      SCABNX=0.0
      DO 27 J=INDI,NCABLE
      IF(ABS(FORS(J))-FCABNX)28,28,29
   29 FCABNX=FORS(J)
      AAAA=J
   28 IF(ABS(CSUB3(J))-SCABNX)27,27,30
   30 SCABNX=CSUB3(J)
      BBBB=J
   27 CONTINUE
      P(979)=FCABNX
      P(941)=SCABNX
      P(942)=BBBB
      P(943)=AAAA
    3 CONTINUE
                RETURN
                END
```

SRC7

```
                SUBROUTINE FORFUN
                DIMENSION Y(100),P(9549),NTEGER(50 ),VAR(9999)
                COMMON VAR
                EQUIVALENCE (VAR(1),Y(1)), (VAR(301),NTEGER(1)),(VAR(451)
     1          ,P(1))
      EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
     1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),AI1),(P(690),A2)
     2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
     36),G2),(P(697),H2),(P(698),AI2)
                EQUIVALENCE (P(128),AGX1PT),(P(129),AGY1PT),(P(130),AGZ1P
     1          T),(P(131),AGX2PT),(P(132),AGY2PT), (P(133),AGZ2PT),(P(13
```

```
2            4),AFX1IT),(P(138),AFY2IT),(P(139),AFZ2IT)
3            ,(P(135),AFY1IT),(P(136),AFZ1IT),(P(137),AFX2IT)
4,(P(5932),FX1G),(P(5933),FY1G),(P(5934),FZ1G)
I=3
GO TO(101,102,103),I
C THE FOLLOWING ARE PRINCIPAL AXES COMPONENTS
101 AGX1PT=P(5958)*SIN(P(5999)*Y(1))
    AGY1PT=P(5957)*SIN(P(5999)*Y(1))
    AGZ1PT=P(5956)*SIN(P(5999)*Y(1))
C THE FOLLOWING ARE SYMMETRY AXES COMPONENTS
    AFX1I =P(5948)*SIN(P(5945)*Y(1))
    AFY1I =P(5947)*SIN(P(5945)*Y(1))
    AFZ1I =P(5946)*SIN(P(5945)*Y(1))
C THE FOLLOWING CARD SHOULD READ AFX2I=0.0.IT WAS CHANGED FOR
C TEST PURPOSES,TO AFX2I=-AFX1I
    AFX2I=0.0
    AFY2I=0.0
    AFZ2I=0.0
    GO TO 1
C THE FOLLOWING ARE PRINCIPAL AXES COMPONENTS
102 AGX2PT=P(5958)*SIN(P(5999)*Y(1))
    AGY2PT=P(5957)*SIN(P(5999)*Y(1))
    AGZ2PT=P(5956)*SIN(P(5999)*Y(1))
C THE FOLLOWING ARE SYMMETRY AXES COMPONENTS
    AFX2I =P(5948)*SIN(P(5945)*Y(1))
    AFY2I =P(5947)*SIN(P(5945)*Y(1))
    AFZ2I =P(5946)*SIN(P(5945)*Y(1))
    AFX1I=0.0
    AFY1I=0.0
    AFZ1I=0.0
    GO TO 1
103 CONTINUE
    AFX1I=0.0
    AFY1I=0.0
    AFZ1I=0.0
    AFX2I=0.0
    AFY2I=0.0
    AFZ2I=0.0
C CALCULATE GRAVITY FORCES ON BOTH BODIES
C THE FOLLOWING ARE SYMMETRY AXES COMPONENTS
  1 FX1G= P(6)*(A1*P(125)+B1*P(126)+C1 *P(127))
    FY1G= P(6)*(D1*P(125)+E1*P(126)+F1 *P(127))
    FZ1G= P(6)*(G1*P(125)+H1*P(126)+A11*P(127))
    FX2G=P(22)*(A2*P(125)+B2*P(126)+C2 *P(127))
    FY2G=P(22)*(D2*P(125)+E2*P(126)+F2 *P(127))
    FZ2G=P(22)*(G2*P(125)+H2*P(126)+A12*P(127))
    AFX1IT=AFX1I+FX1G
    AFY1IT=AFY1I+FY1G
    AFZ1IT=AFZ1I+FZ1G
    AFX2IT=AFX2I+FX2G
    AFY2IT=AFY2I+FY2G
    AFZ2IT=AFZ2I+FZ2G
    RETURN
          END
```

SRC8

```
          SUBROUTINE OUTPUT
          DIMENSION Y(100),DYDX(100),P(9549),NTEGER(50 ),VAR(9999),
1REC(39)
 COMMON   VAR ,KNT, KFST
          EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(301),
1         NTEGER(1)),(VAR(451),P(1))
4,(P(5991),YCG),(P(5990),XCG),(P(5989),ZCG),(P(5988),XBR2CG),(P(59
587),YBR2CG),(P(5986),ZBR2CG),(P(5985),PSICAP),(P(5984),PHICAP)
 EQUIVALENCE(P(5970),EX2),(P(5969),EY2),(P(5968),EZ2)
 EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),AI1),(P(690),A2)
2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
36),G2),(P(697),H2),(P(698),AI2),(NTEGER(32),NPP)
 EQUIVALENCE (P(7669),YHSMX),(P(7670),NPHS),(P(7671),YR1MX),
1(P(7672),NPR1),(P(7673),YR2MX),(P(7674),NPR2),(P(7675),YR3MX),
2(P(7676),NPR3)
 B=57.2957795
 OUT1=(P(10)*DYDX(2)+P(11)*DYDX(3)+P(12)*DYDX(4))*B
 OUT2=(P(13)*DYDX(2)+P(14)*DYDX(3)+P(15)*DYDX(4))*B
 OUT3=(P(16)*DYDX(2)+P(17)*DYDX(3)+P(18)*DYDX(4))*B
 OUT7=P(56)*B
 OUT8=P(57)*B
 OUT9=P(58)*B
 OUT4 =(P(26)*DYDX(11)+P(27)*DYDX(12)+P(28)*DYDX(13))*B
 OUT5 =(P(29)*DYDX(11)+P(30)*DYDX(12)+P(31)*DYDX(13))*B
 OUT6 =(P(32)*DYDX(11)+P(33)*DYDX(12)+P(34)*DYDX(13))*B
 OUT10=P(59)*B
 OUT11=P(60)*B
 OUT12=P(61)*B
 OUT13=DYDX(8 )*B
 OUT14=DYDX(9 )*B
 OUT15=DYDX(10)*B
 OUT16=DYDX(17)*B
 OUT17=DYDX(18)*B
 OUT18=DYDX(19)*B
 OUT19=Y(8)*B
 OUT20= Y  (9 )*B
 OUT21= Y  (10)*B
 OUT22= Y  (17)*B
 OUT23= Y  (18)*B
 OUT24= Y  (19)*B
 OUT25=P(1221)*B
 OUT26=P(1222)*B
 OUT27=P(1223)*B
 OUT30=DYDX( 5)+P(57)*Y( 7)-P(58)*Y( 6)
 OUT31=DYDX( 6)+P(58)*Y( 5)-P(56)*Y( 7)
 OUT32=DYDX( 7)+P(56)*Y( 6)-P(57)*Y( 5)
 OUT33=DYDX(14)+P(60)*Y(16)-P(61)*Y(15)
 OUT34=DYDX(15)+P(61)*Y(14)-P(59)*Y(16)
 OUT35=DYDX(16)+P(59)*Y(15)-P(60)*Y(14)
 OUT36=Y(20)*B
 OUT37=Y(22)*B
 OUT38=Y(21)*B
 P(973 )=     A1 *OUT30  +    D1 *OUT31  +    G1 *OUT32
 P(974 )=     B1 *OUT30  +    E1 *OUT31  +    H1 *OUT32
 P(975 )=     C1 *OUT30  +    F1 *OUT31  +AI1*OUT32
 P(976 )=     A2 *OUT33  +    D2 *OUT34  +    G2 *OUT35
 P(977 )=     B2 *OUT33  +    E2 *OUT34  +    H2 *OUT35
 P(978 )=     C2 *OUT33  +    F2 *OUT34  +    AI2*OUT35
```

```
C   CALCULATE STABILITY ANGLE(SANG IN OUTPUT)
      AIIG=P(5932)/P(6)
      AJIG=P(5933)/P(6)
      AKIG=P(5934)/P(6)
      AIIV=AI*DYDX(23)+CI*DYDX(25)
      AJIV=DI*DYDX(23)+FI*DYDX(25)
      AKIV=GI*DYDX(23)+AII*DYDX(25)
      AJIN=AKIG*AIIV-AKIV*AIIG
      AKIN=AIIG*AJIV-AIIV*AJIG
      AIIN=AJIG*AKIV-AJIV*AKIG
      SUB2=AKIN/AIIN
      SUB1=(AJIN*P(5930)/AIIN)+P(965)
      SUB3=(SUB1*SUB2-P(967))/(SUB2**2+1.0)
      SUB4=(SUB1**2-P(5931)**2+P(967)**2)/(SUB2**2+1.0)
      AINTG=SUB3**2-SUB4
      IF(AINTG)51,52,52
   51 STAANG=-1.0E10
      GO TO 58
   52 PKI=(SQRT(AINTG))*(AKIV/ABS(AKIV))-SUB3
      EDSUB=(P(5931)**2)-(PKI-P(967))**2
      IF(EDSUB)60,60,61
   60 EDSUB=0.00001
   61 PII=(SQRT(EDSUB)*AIIV/ABS(AIIV))+P(965)
      STAANG=ARCOS(ABS((AJIG*P(5930)+AKIG*PKI+AIIG*PII)/SQRT((AJIG**2+
     1AKIG**2+AIIG**2)*(P(5930)**2+PKI**2+PII**2))))
      STAANG=STAANG/0.017453
      AJABS=ABS(AJIN)
      AKABS=ABS(AKIN)
      AIABS=ABS(AIIN)
      IF(AJABS-AKABS)53,53,54
   53 IF(AKABS-AIABS)55,55,56
   54 IF(AJABS-AIABS)55,55,57
   55 AIINA=AJIG*PKI-P(5930)*AKIG
      STAANG=STAANG*AIIN*ABS(AIINA)/(AIINA*AIABS)
      GO TO 58
   56 AKINA=AIIG*P(5930)-PII*AJIG
      STAANG=STAANG*AKIN*ABS(AKINA)/(AKINA*AKABS)
      GO TO 58
   57 AJINA=AKIG*PII-PKI*AIIG
      STAANG=STAANG*AJIN*ABS(AJINA)/(AJINA*AJABS)
   58 CONTINUE
      IF(NTEGER(25))301,301,302
  302 NPP=NPP+1
      EDA=P(59)*P(7666)+P(60)*P(7667)+P(61)*P(7668)
      EDB=P(59)**2+P(60)**2+P(61)**2
      EDC=OUT5*P(7668)-OUT6*P(7667)
      EDD=OUT6*P(7666)-OUT4*P(7668)
      EDE=OUT4*P(7667)-OUT5*P(7666)
      REC(1 )=Y(1)
      REC(2 )=P(402)
      REC(3 )=P(403)
      REC(4 )=P(404)
      REC(5)=P(405)
      REC(6)=P(406)
      REC(7)=P(407)
      REC(8 )=P(662)
      REC(9 )=P(663)
      REC(10)=P(664)
      REC(11)=P(665)
      REC(12)=P(666)
      REC(13)=P(667)
      REC(14)=P(202)
      REC(15)=P(203)
      REC(16)=P(204)
```

```
      REC(17)=P(205)
      REC(18)=P(206)
      REC(19)=P(207)
      REC(20)=P(459)
      REC(21)=P(460)
      REC(22)=P(441)
      REC(23)=P(450)
      REC(24)=Y(23)
      REC(25)=Y(24)
      REC(26)=Y(25)
      REC(27)=OUT32
      REC(28)=OUT31
      REC(29)=SQRT(OUT30**2+OUT31**2+OUT32**2)
      REC(30)= SQRT(OUT33**2+OUT34**2+OUT35**2)
      REC(31)=DYDX(23)
      REC(32)=OUT33+EDA*P(59)-EDB*P(7666)+EDC*0.017453
      REC(33)=OUT19
      REC(34)=DYDX(24)
      REC(35)=OUT34+EDA*P(60)-EDB*P(7667)+EDD*0.017453
      REC(36)=OUT20
      REC(37)=DYDX(25)
      REC(38)=OUT35+EDA*P(61)-EDB*P(7668)+EDE*0.017453
      REC(39)=OUT21
      WRITE(9)(REC(I),I=1,39)
  301 CONTINUE


      IF(Y(1)-P(2))20,50,50
   20 IF(Y(1)-P(8))150,50,50
   50 CONTINUE
      WRITE(6,100)P(973 ),P(974 ),P(975 ),P(976 ),P(977 ),P(978 ),
     1DYDX(23),DYDX(24),DYDX(25),DYDX(26),DYDX(27),DYDX(28),Y(23),
     2Y(24),Y(25),Y(26),Y(27),Y(28),
     3 OUT1,OUT2,
     4OUT3,OUT4,OUT5,OUT6
      WRITE(6,206)OUT7,OUT8,OUT9,OUT10,OUT11,OUT12,P(200),P(5998),P(979)
     1,P(943),P(699),P(700),OUT19,OUT20,OUT21,OUT22,OUT23,OUT24
      WRITE(6,207)Y(1),OUT36,OUT37,OUT38,P(941),P(942)
      WRITE(6,208)P(821),P(841),P(861),P(2751),P(2752),STAANG
      EMAG1=P(4174)+P(6999)
      EMAG2=P(4175)+P(7000)
      EMAG3=P(4176)+P(7001)
      EMAG4=P(4177)+P(7002)
      EMAG5=P(4178)+P(7003)
      EMAG6=P(4179)+P(7004)
      WRITE(6,209)EMAG1,EMAG2,EMAG3,EMAG4,EMAG5,EMAG6
      WRITE(6,210)P(7669),NPHS    ,P(7671),NPR1    ,P(7673),NPR2    ,P(7675
     1),NPR3
  210 FORMAT(5H YHSME15.8,7H    NPHSI15   ,7H    YR1ME15.8,7H    NPR1I15   ,7
     1H    YR2ME15.8,7H    NPR2I15   /5H YR3ME15.8,7H    NPR3I15///)
  100 FORMAT(5H X1DDE15.8,7H    Y1DDE15.8,7H    Z1DDE15.8,7H    X2DDE15.8,700000014
     2H    Y2DDE15.8,7H    Z2DDE15.8/5H X1D E15.8,7H    Y1D E15.8,7H    Z1D 0000143
     3E15.8,7H    X2D E15.8,7H    Y2D E15.8,7H    Z2D E15.8/5H X1  E15.8,7H00001440
     4    Y1  E15.8,7H    Z1  E15.8,7H    X2  E15.8,7H    Y2  E15.8,7H    Z2
     5 E15.8/
     6                                                        5H OX1DE15.8,7
     7H    OY1DE15.8,7H    OZ1DE15.8,7H    OX2DE15.8,7H    OY2DE15.8,7H    OZ
     82DE15.8)
  206 FORMAT(5H OX1 E15.8,7H    OY1 E15.8,7H    OZ1 E15.8,7H    OX2 E15.8,700001420
     2H    OY2 E15.8,7H    OZ2 E15.8/5H FSMXE15.8,7H    S NOE15.8,7H    FHMA00001430
     3E15.8,7H    H NOE15.8,7H    SSMXE15.8,7H    S NOE15.8/5H TH1 E15.8,7H00001
     4    PH1 E15.8,7H    PS1 E15.8,7H    TH2 E15.8,7H    PH2 E15.8,7H    PS2
     5 E15.8)
```

```
207 FORMAT(5H TIMEE15.8,7H    THBRE15.8,7H    PSBRE15.8,7H    PHBRE15.8,7
   2H    SHMXE15.8,7H    H NOE15.8)
208 FORMAT(5H XBRIE15.8,7H    YBRIE15.8,7H    ZBRIE15.8,7H    SE3PE15.8,7
   2H    SE3ME15.8,7H    SANGE15.8)
209 FORMAT(5H FXGRE15.8,7H    FYGRE15.8,7H    FZGRE15.8,7H    GXGRE15.8,7
   1H    GYGRE15.8,7H    GZGRE15.8)
    P(8)=P(8)+P(7)
    NTEGER(23)=NTEGER(23)+1
    IF(NTEGER(23)-2)120,121,121
121 WRITE(6,122)
122 FORMAT(1H1)
    NTEGER(23)=0
120           IF(Y(1) - P(2))150,130,130
130 END FILE 11
    END FILE 9
150 CONTINUE
     RETURN
              END
```

SRC9

```
      SUBROUTINE SIDSHK
      DIMENSION P(9549),VAR(9999),NTEGER(50)
      COMMON VAR
      EQUIVALENCE(VAR(451),P(1)),(P(68),GAMB11),(P(69),GAMB12),(P(70),
     1GAMB13),(P(71),GAMB21),(P(72),GAMB22),(P(73),GAMB23),(P(74),GAMB
     231),(P(75),GAMB32),(P(76),GAMB33),(P(437),XBP2PL),(P(421),XBP1PL),
     3(P(821),XB1),(P(426),YBP2PL),(P(429),ZBP2PL),(P(459),STROKP),(VAR
     4(301),NTEGER(1)),(NTEGER(20),NLATP),(P(2751),SEVC3P),(P(2745),ELI
     5CS),(P(2744),BKC1S),(P(2747),SC1S),(P(2753),FEC13P),(P(2746),AKPS)
     6,(P(438),XBP2ML),(P(424),XBP1ML),(P(431),YBP2ML),(P(432),ZBP2ML),
     7(P(460),STROKM),(P(427),XBP2PI),(P(430),XBP2MI),(NTEGER(19),NLATM)
     8,(P(2752),SEVC3M),(P(2754),FEC13M),(P(841),YB1),(P(861),ZB1)
C   CHECK RIGHT SIDE(+) STRUT
      XBP2PL=(XBP1PL-XB1-GAMB21*YBP2PL-GAMB31*ZBP2PL)/GAMB11
      STROKP=XBP2PL-XBP2PI
      IF(STROKP)2,1,1
    1 NLATP=1
      GO TO 11
    2 IF(SEVC3P-STROKP)3,3,4
    4 IF(-STROKP-ELICS)5,5,6
    5 P(441)=BKC1S*STROKP
      NLATP=-1
      GO TO 10
    6 P(441)=-SC1S
      NLATP=-1
      GO TO 10
    3 P(441)=FEC13P-AKPS*(SEVC3P-STROKP)
      NLATP=1
      IF(P(441))10,11,11
   10 YBP1PL=YB1+GAMB12*XBP2PL+GAMB22*YBP2PL+GAMB32*ZBP2PL
      ZBP1PL=ZB1+GAMB13*XBP2PL+GAMB23*YBP2PL+GAMB33*ZBP2PL
C   POINT P1+L IS NOW COINCIDENT WITH TIP OF LATERAL STRUT
C   COMPUTE FORCES AND TORQUES (SYMMETRY AXES)
      P(442)=(-1.0)*GAMB11*P(441)
      P(443)=(-1.0)*GAMB12*P(441)
      P(444)=(-1.0)*GAMB13*P(441)
      P(445)=YBP1PL*P(444)-ZBP1PL*P(443)
      P(446)=ZBP1PL*P(442)-XBP1PL*P(444)
```

```
      P(447)=XBP1PL*P(443)-YBP1PL*P(442)
      P(448)=ZBP2PL*P(441)
      P(449)=(-1.0)*YBP2PL*P(441)
      GO TO 12
   11 DO 7 J=1,9
    7 P(J+440)=0.0
C     CHECK LEFT SIDE(-) STRUT
   12 XBP2ML=(XBP1ML-XB1-GAMB21*YBP2ML-GAMB31*ZBP2ML)/GAMB11
      STROKM=XBP2ML-XBP2MI
      IF(STROKM)13,13,14
   13 NLATM=1
      GO TO 20
   14 IF(STROKM-SEVC3M)15,15,16
   16 IF(STROKM-ELICS)17,17,18
   17 P(450)=BKCIS*STROKM
      NLATM=-1
      GO TO 19
   18 P(450)=SCIS
      NLATM=-1
      GO TO 19
   15 P(450)=FEC13M-AKPS*(SEVC3M-STROKM)
      NLATM=1
       IF(P(450))20,20,19
   19 YBP1ML=YB1+GAMB12*XBP2ML+GAMB22*YBP2ML+GAMB32*ZBP2ML
      ZBP1ML=ZB1+GAMB13*XBP2ML+GAMB23*YBP2ML+GAMB33*ZBP2ML
C     POINT P1-L IS NOW COINCIDENT WITH TIP OF LATERAL STRUT
C     COMPUTE FORCES AND TORQUES (SYMMETRY AXES)
      P(451)=(-1.0)*GAMB11*P(450)
      P(452)=(-1.0)*GAMB12*P(450)
      P(453)=(-1.0)*GAMB13*P(450)
      P(454)=YBP1ML*P(453)-ZBP1ML*P(452)
      P(455)=ZBP1ML*P(451)-XBP1ML*P(453)
      P(456)=XBP1ML*P(452)-YBP1ML*P(451)
      P(457)=ZBP2ML*P(450)
      P(458)=(-1.0)*YBP2ML*P(450)
      GO TO 21
   20 DO 22 J=1,9
   22 P(J+449)=0.0
   21 CONTINUE
      RETURN
      END
```

SRC10

```
      SUBROUTINE SOILF
      DIMENSION P(9549),VAR(9999),YB2S1(200),FVO(200),YB2S10(200),
     1NTEGER(50),AC(200),XB2RTS(200),YB2RTS(200),ZB2RTS(200),VECTB(200)
      COMMON VAR
      EQUIVALENCE (VAR(451),P(1)),(P(2755),XB2DS1),(P(2756),YB2DS1),
     1(P(2757),ZB2DS1),(P(2758),YB2S1(1)),(P(2958),FVO(1)),(P(3158),
     2YB2S10(1)),(P(4180),XB2RTS(1)),(P(4380),YB2RTS(1)),(P(4580),ZB2RTS
     3(1)),(P(3758),VECTB(1))
     3,(VAR(301),NTEGER(1)),(NTEGER(31),J),(P(6000),ANG),(P(3964),AKC)
     4,(P(3958),CGO),(P(3960),DENSTY),(P(3959),CDO),(P(3961),GCONST),
     5(P(3962),GPOWER),(P(3963),HOFF),(P(3965),AKNT),(P(3966),AMU),(P(3
     6 970),AC(1)),(P(4170),FSR),(P(4171),FVT),(P(4172),FDX),(P(4173
     7 ),FDZ)
      IF(YB2S1(J)-YB2S10(J))1,1,2
    1 FVS=(GCONST*AC(J)*(-YB2S1(J))**GPOWER)/11.0447
      GO TO 3
```

```
    2 FVS=FVO(J)+BOFF*(YB2SIO(J)-YB2SI(J))*AC(J)/11.0477
      IF(FVS)4,4,5
    4 FVS=0.0
      GO TO 5
    3 IF(YB2DS1)10,11,11
   11 FDYNA=0.0
      GO TO 6
   10 DYNAM=0.5*DENSTY*AC(J)*AKC.YB2DS1**2
      CONE=AKNT*(-YB2SI(J))*AC(J)/11.0447
      IF(CONE-DYNAM)7,7,8
    7 FDYNA=CONE
      GO TO 6
    8 FDYNA=DYNAM
    6 FVT=FVS+FDYNA
      GO TO 9
    5 FVT=FVS
C   CHECK FOR DRAG FORCE ON THE PAD
    9 IF(FVS)13,13,14
   13 AF=0.0
      GO TO 12
   14 GAMMA=ATAN2(ZB2RTS(J),XB2RTS(J))
      BEE=ATAN2(ZB2DS1,XB2DS1)
      GRAA=GAMMA-BEE
      IF(XB2RTS(J))15,16,16
   15 IF(ZB2RTS(J))17,18,19
C   IN THIRD QUADRANT
   17 IF(GRAA+4.7122)20,20,16
   20 GRAA=GRAA+6.28318
      GO TO 16
C   IN FORTH QUADRANT
   19 IF(GRAA-4.7122)16,21,21
   21 GRAA=GRAA-6.28318
      GO TO 16
   18 WRITE(6,22)J
   22 FORMAT(19H CANT TELL IF POINTI4,52H IS IN QUADRANT 3 OR 4.ASSUME D
     1RAG IS 0 AND CONTINUE)
   16 CONTINUE
C   CHECK DRAG FORCE CONDITION
      IF(ABS(GRAA)-1.5707)23,13,13
C   HAVE DRAG FORCE
C   ASSUME AREA ASSIGNED TO GIVEN POINT IS SQUARE AND COMPUTE SIDE OF IT
   23 ACSIDE=SQRT(AC(J))
      WPA=ACSIDE*COS(GRAA)
      THTO=ARCOS(ABS(YB2RTS(J))/VECTB(J))
      HPA=ACSIDE*SIN(THTO)
C   COMPUTE FRONTAL(PROJECTED)AREA OF POINT
      AF=HPA*WPA
   12 FD1=CG0*DENSTY*(-YB2SI(J))*AF*ANG
      FD2=CD0*DENSTY*AF*(XB2DS1**2+ZB2DS1**2)
      FD=FD1+FD2+AMU*FVT
C    COMPUTE RESULTANT VELOCITY IN INERTIAL X-Z PLANE
      TVB2SI=SQRT(XB2DS1**2+ZB2DS1**2)
C   RESOLVE DRAG FORCE INTO INERTIAL X AND Z COMPONENTS
      FDX=(-FD)*XB2DS1/TVB2SI
      FDZ=(-FD)*ZB2DS1/TVB2SI
C   DETERMINE RESULTANT SOIL FORCE
      FSR=SQRT(FDX**2+FDZ**2+FVT**2)
      RETURN
      END
```

SRC11

```
      FUNCTION SINE(X)
      SINE=SIN(X)
      RETURN
      END
```

SRC12

```
      FUNCTION ARTN(X,Y)
      ARTN=ATAN2(X,Y)
      RETURN
      END
```

SRC13

```
      SUBROUTINE GROFOR
      DIMENSION Y(100),P(9549),NTEGER(50),VAR(9999),YB2S1(200),FPR(200)
     1,XB2RTS(200),YB2RTS(200),ZB2RTS(200),VECTB(200)
      COMMON VAR
      EQUIVALENCE (VAR(1),Y(1)),(VAR(301),NTEGER(1)),(VAR(451),P(1)),
     1(NTEGER(5),NSK),(P(56),OMX1),(P(57),OMY1),(P(58),OMZ1),(P(2755),
     2XB2DS1),(P(2756),YB2DS1),(P(2757),ZB2DS1),(P(2758),YB2S1(1)),(P
     3(4170),FSR),(P(4171),FVT),(P(4172),FDX),(P(4173),FDZ),(P(3358),
     4FPR(1)),(P(3758),VECTB(1)),(P(4180),XB2RTS(1)),(P(4380),YB2RTS(1))
     5,(P(4580),ZB2RTS(1))
      EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
     1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),AI1),(P(690),A2)
     2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
     36),G2),(P(697),H2),(P(698),AI2)
C     INITIALIZE GROUND FORCES AND TORQUES ON BODY 1 TO ZERO
      P(4174)=0.0
      P(4175)=0.0
      P(4176)=0.0
      P(4177)=0.0
      P(4178)=0.0
      P(4179)=0.0
      DO 1 J=1,NSK
C     DETERMINE WHICH POINTS ARE BELOW INERTIAL XZ PLANE
      YB2S1(J)=Y(24)+B1*P(J+1582)+E1*P(J+1782)+H1*P(J+1982)
      IF(YB2S1(J))2,3,3
C     COMPUTE INERTIAL VELOCITY OF POINTS BELOW XZ PLANE
C     VELOCITY IN SYMMETRY AXIS SYSTEM
    2 VELI=Y(5)-OMZ1*P(J+1782)+OMY1*P(J+1982)
      VELJ=Y(6)-OMX1*P(J+1982)+OMZ1*P(J+1582)
      VELK=Y(7)+OMX1*P(J+1782)-OMY1*P(J+1582)
C     VELOCITY IN INERTIAL SYSTEM
      XB2DS1    =A1*VELI+D1*VELJ+G1*VELK
      YB2DS1    =B1*VELI+E1*VELJ+H1*VELK
      ZB2DS1    =C1*VELI+F1*VELJ+AI1*VELK
C     CALCULATE POSITION VECTOR FROM RC TO S1(J) IN INERTIAL COORDINATES
      SUB1=P(J+1582)-P(965)
      SUB2=P(J+1782)-P(969)
      SUB3=P(J+1982)-P(967)
      XB2RTS(J)=A1*SUB1+D1*SUB2+G1*SUB3
```

```
      YB2RTS(J)=B1*SUB1+E1*SUB2+H1*SUB3
      ZB2RTS(J)=C1*SUB1+F1*SUB2+A11*SUB3
      VECTB(J)=SQRT(XB2RTS(J)**2+YB2RTS(J)**2+ZB2RTS(J)**2)
      NTEGER(31)=J
      CALL SOILF
C   TRANSFORM GROUND FORCES FROM INERTIAL AXES TO BODY 1 AXES
      FDX1=A1*FDX+B1*FVT+C1 *FDZ
      FVT1=D1*FDX+E1*FVT+F1 *FDZ
      FDZ1=G1*FDX+H1*FVT+A11*FDZ
C   COMPUTE TOTAL FORCES AND TORQUES ON BODY1 DUE TO GROUND
      P(4174)=P(4174)+FDX1
      P(4175)=P(4175)+FVT1
      P(4176)=P(4176)+FDZ1
      P(4177)=P(4177)+FDZ1*P(J+1782)-FVT1*P(J+1982)
      P(4178)=P(4178)-FDZ1*P(J+1582)+FDX1*P(J+1982)
      P(4179)=P(4179)+FVT1*P(J+1582)-FDX1*P(J+1782)
C   DETERMINE THE COSINE OF THE ANGLE BETWEEN VECTB AND FSR
      CSAB=(FDX*XB2RTS(J)+FVT*YB2RTS(J)+FDZ*ZB2RTS(J))/(VECTB(J)*FSR)
C   DETERMINE SOIL FORCE COMPONENT NORMAL TO HEAT SHIELD
      FPR(J)=(-FSR)*CSAB
      GO TO 1
    3 YB2S1(J)=0.0
      FPR(J)=0.0
    1 CONTINUE
      RETURN
      END
```

SRC14

```
      SUBROUTINE RKAM
      DIMENSION T(1000)
      COMMON/ADM/T,NN,SPACE,KA1,A1,A2,A3,A4,A5,A7,MAP,SSE,YP,KPRNT
      DIMENSION BET(4),SET(4)
      DATA(BET(I),I=1,4)/2*0.5,1.0,0.0/,(SET(I),I=1,4)/1.0,2*2.0,1.0/
      GO TO (502,412,503,411),MAP
  502 N1=NN+1
      N2XN1=N1+N1
      N3XN1=N2XN1+N1
      N4XN1=N3XN1+N1
      N5XN1=N4XN1+N1
      N7XN1=N3XN1+N4XN1
      N10XN1=N5XN1+N5XN1
      N12XN1=N10XN1+N2XN1
      CALL DERFUN
  411 LL=1
      KR=1
      MAP=2
      ION=0
      RETURN
  412 DO 415 I=1,KR
      LRR=N3XN1*(KR-I+1)
      DO 415 J=1,N3XN1
      LR=LRR+J
      LRJ=LR-N3XN1
      T(LR)=T(LRJ)
  415 CONTINUE
  414 MAP=2
      IF(KR.GE.4)GO TO 44
  413 DO 20 I=1,NN
      IP2N1=I+N2XN1
      T(IP2N1)=0.0
```

```
 20 CONTINUE
    K=1
 32 DO 350 I=1,NN
    IPN1=I+N1
    IP2N1=I+N2XN1
    IP3N1=I+N3XN1
    DELYI=SPACE*T(IPN1)
    T(IP2N1)=T(IP2N1)+SET(K)*DELYI
350 T(I)=T(IP3N1)+BET(K)*DELYI
    IF(K.GE.4)GO TO 37
 33 T(N1)=T(N4XN1)+BET(K)*SPACE
    CALL DERFUN
    K=K+1
    GO TO 32
 37 DO 40 I=1,NN
    IP2N1=I+N2XN1
    IP3N1=I+N3XN1
    IP5N1=I+N5XN1
    CALL DPFAD(T(IP3N1),T(IP5N1),T(IP2N1)/6.0,T(I),T(IP2N1))
 40 CONTINUE
    T(N1)=T(N4XN1)+SPACE
    CALL DERFUN
    IF(KA1.LT.0)GO TO 506
507 KR=KR+1
    KPRNT=KPRNT+1
506 IF(KA1.GT.0)GO TO 556
    RETURN
556 IF(ION.NE.1)GO TO 412
    RETURN
 44 ION=0
    DO 48 I=1,NN
    IP3N1=I+N3XN1
    IP4N1=I+N4XN1
    IP7N1=I+N7XN1
    IP10N1=I+N10XN1
    IP13N1=IP10N1+N3XN1
    DEL=SPACE*(55.*T(IP4N1)-59.*T(IP7N1)+37.*T(IP10N1)-9.*T(IP13N1))/
   1     24.0
    T(I)=T(IP3N1)+DEL
    YP=T(I)
 48 CONTINUE
    T(N1)=T(N4XN1)+SPACE
    CALL DERFUN
    SSE=0.0
    KBAKP=0
    KBAK=0
    DO 51 I=1,NN
    IP5N1=I+N5XN1
    IPN1=I+N1
    IP4N1=I+N4XN1
    IP2N1=I+N2XN1
    IP7N1=I+N7XN1
    IP10N1=I+N10XN1
    IP3N1=I+N3XN1
    DEL=SPACE*(9.*T(IPN1)+19.*T(IP4N1)-5.*T(IP7N1)+T(IP10N1))/24.0
    YI=T(IP3N1)+DEL
    IF(KA1.EQ.0)GO TO 103
304 IF(ABS(YI).GT.A1)GO TO 301
303 EPSIL=ABS(-19.0*(YI-T(I))/270.0)
    GO TO 307
301 EPSIL=ABS(-19.0*(YI-T(I))/(270.0*YI))
307 IF(KA1.EQ.0)GO TO 6969
    GO TO 704
```

```
6969 CALL ERROR(YI,I,ERO)
     IF(ERO.LT.EPSIL)GO TO 701
     GO TO 704
 701 KBAKP=KBAKP+1
     KBAK=1
 704 IF(SSE.GE.EPSIL)GO TO 302
     SSE=EPSIL
 302 CALL DPFAD(T(IP3N1),T(IP5N1),DEL,T(I),T(IP2N1))
  51 CONTINUE
     IF(KBAKP)600,600,601
 601 WRITE(6,602)KBAKP
 602 FORMAT(1H I3,16H ERRORS.GO TO RK)
 600 CALL DERFUN
     IF(KA1.EQ.0)GO TO 702
     GO TO 705
 702 IF(KBAK.EQ.1)GO TO 703
     GO TO 39
 703 KBAK=0
     GO TO 342
 705 IF(A2.GT.SSE)GO TO 35
     IF(ABS(SPACE).GT.A4)GO TO 340
     ION=1
     GO TO 342
  35 IF(SSE.GE.A3)GO TO 39
     IF(ABS(SPACE).LT.A5)GO TO 360
  39 CONTINUE
     LL=2
     KR=4
     RETURN
 340 SPACE=SPACE*A7
     GO TO(341,342),LL
 341 DO 501 I=1,N3XN1
     IP12N1=I+N12XN1
     T(I)=T(IP12N1)
 501 CONTINUE
 504 LL=1
     IF(KA1)603,604,603
 604 KR=3
     GO TO 412
 603 KR=1
     GO TO 412
 342 DO 343 I=1,N3XN1
     IP3N1=I+N3XN1
     T(I)=T(IP3N1)
 343 CONTINUE
     IF(ION.EQ.1)GO TO 555
     GO TO 504
 555 LL=2
     KR=1
     GO TO 412
 360 MAP=3
     RETURN
 503 DO 362 I=1,N3XN1
     IP3N1=I+N3XN1
     IP9N1=I+N5XN1+N4XN1
     IP12N1=I+N12XN1
     T(IP3N1)=T(I)
     T(IP9N1)=T(IP12N1)
 362 CONTINUE
     KR=3
     SPACE=2.0*SPACE
     GO TO 414
     END
```

SRC15

```
      SUBROUTINE DPFAD(AA,BB,CC,DD,EE)
      DOUBLE PRECISION A1,B1,C1
      EQUIVALENCE (A1,A(1)),(B1,A(3)),(C1,A(5))
      DIMENSION A(6)
      DATA A(4)/0.0/
      A(1)=AA
      A(2)=BB
      A(3)=CC
      C1=A1+B1
      DD=A(5)
      EE=A(6)
      RETURN
      END
```

SRC16

```
      SUBROUTINE ERROR(YI,I,ERO)
C
      KNT=0
      YCK=ABS(YI)
      IF(YCK.LT.1.0)GO TO 10
      LOB=YCK
   11 KNT=KNT+1
      LOB=LOB/10
      IF(LOB.EQ.0)GO TO 12
      GO TO 11
   12 ERO=10.0**KNT/10.0**4
      GO TO 13
   10 IF(YCK.LE..1E-0 )GO TO 15
   14 YCK=10.0*YCK
      IF(YCK.GE.1.0)GO TO 12
      KNT=KNT-1
      GO TO 14
   15 ERO=.1E-3
   13 RETURN
      END
```

SRC17

```
      SUBROUTINE RINGF
      DIMENSION Y(100),P(9549),NTEGER(50),VAR(9999),YB2RI(72),XB2RSN(72)
     1,YB2RSN(72),ZB2RSN(72),VECTBN(72),FVRIO(72),YB2RIO(72),DELEQU(72)
      COMMON VAR
      EQUIVALENCE(VAR(1),Y(1)),(VAR(301),NTEGER(1)),(VAR(451),P(1)),
     1(P(56),OMX1),(P(57),OMY1),(P(58),OMZ1),(P(7005),FSRI),(P(7006),
     2FVTR),(P(7007),FDZR),(P(7008),FDXR),(P(5938),THTO),(P(3963),BUFF)
     3,(P(6927),YB2RI(1)),(P(6855),FVRIO(1)),(P(6783),YB2RIO(1))
     4,(P(7231),DELEQU(1)),(P(7378),VECTBN(1)),(P(7450),YB2RSN(1)),(P(
     57522),XB2RSN(1)),(P(7594),ZB2RSN(1))
      EQUIVALENCE (P(681),A1),(P(682),B1),(P(683),C1),(P(684),D1),(P(685
     1),E1),(P(686),F1),(P(687),G1),(P(688),H1),(P(689),AI1),(P(690),A2)
     2,(P(691),B2),(P(692),C2),(P(693),D2),(P(694),E2),(P(695),F2),(P(69
     36),G2),(P(697),H2),(P(698),AI2)
```

```
C   INITIALIZE GROUND FORCES AND TORQUES ON BODY 1 TO ZERO
      P(6999)=0.0
      P(7000)=0.0
      P(7001)=0.0
      P(7002)=0.0
      P(7003)=0.0
      P(7004)=0.0
      DO 1 J=1,72
C   DETERMINE WHICH POINTS ARE BELOW INERTIAL XZ PLANE
      YB2RI(J)=Y(24)+B1*P(J+6563)+E1*P(J+6635)+H1*P(J+6707)
      IF(YB2RI(J))2,3,3
C   COMPUTE INERTIAL VELOCITY OF POINTS BELOW XZ PLANE
    2 VELIR=Y(5)-OMZ1*P(J+6635)+OMY1*P(J+6707)
      VELJR=Y(6)-OMX1*P(J+6707)+OMZ1*P(J+6563)
      VELKR=Y(7)+OMX1*P(J+6635)-OMY1*P(J+6563)
      XB2DR=A1*VELIR+D1*VELJR+G1*VELKR
      YB2DR=B1*VELIR+E1*VELJR+H1*VELKR
      ZB2DR=C1*VELIR+F1*VELJR+AI1*VELKR
C   CALCULATE POSITION VECTOR FROM RS1,2,3 TO S1RS1,2,3(J) IN INERTIAL CO
C     ORDINATES.
      SUB1A=P(J+6563)-P(965)
      SUB3A=P(J+6707)-P(967)
      IF(J-24)11,11,12
   11 SUB2A=P(J+6635)-P(6780)
      GO TO 15
   12 IF(J-48)13,13,14
   13 SUB2A=P(J+6635)-P(6781)
      GO TO 15
   14 SUB2A=P(J+6635)-P(6782)
   15 XB2RSN(J)=A1*SUB1A+D1*SUB2A+G1*SUB3A
      YB2RSN(J)=B1*SUB1A+E1*SUB2A+H1*SUB3A
      ZB2RSN(J)=C1*SUB1A+F1*SUB2A+AI1*SUB3A
      VECTBN(J)=SQRT(XB2RSN(J)**2+YB2RSN(J)**2+ZB2RSN(J)**2)
      IF(NTEGER(1))6001,6000,6000
 6001 IF(YB2RSN(J))4,3,3
    4 CONTINUE
      YB2RIA=YB2RSN(J)
      VECTBI=VECTBN(J)
      ZB2RSI=ZB2RSN(J)
      XB2RSI=XB2RSN(J)
      FVROI=FVRIO(J)
      IF(J-24)16,16,17
   16 AREAR=P(6561)
      RIRX=P(7010)
      RIRY=P(7009)
      GO TO 20
   17 IF(J-48)18,18,19
   18 AREAR=P(6562)
      RIRX=P(7012)
      RIRY=P(7011)
      GO TO 20
   19 AREAR=P(6563)
      RIRX=P(7014)
      RIRY=P(7013)
   20 YB2ROI=YB2RIO(J)
      YB2IR=YB2RI(J)
      CALL SOILRI(YB2IR,YB2ROI,AREAR,FVROI,YB2DR,ZB2RSI,XB2RSI,ZB2DR,XB2
     1DR,YB2RIA,VECTBI)
C   DETERMINE THE COSINE OF THE ANGLE BETWEEN VECTBN AND FSRI
      CSAB1=(FDXR*XB2RSN(J)+FVTR*YB2RSN(J)+FDZR*ZB2RSN(J))/(VECTBN(J)*
     1FSRI)
C   DETERMINE SOIL FORCE COMPONENT NORMAL TO HEAT SHIELD
      FPR1=(-FSRI)*CSAB1
      IF(FPR1)3,3,5
```

```
    5 COTHTO=COS(THTO)
      IF(YB2RI(J)-YB2RIO(J))6,7,7
C   THE FOLLOWING COULD GIVE TROUBLE WHEN COTHTO IS SMALL
    6 DELS1=ABS((YB2RI(J)-YB2RIO(J))/COTHTO)
      DELS2=ABS((FVRIO(J)*11.0447)/(BOFF*AREAR*COTHTO))
      DELSM1=DELS1+DELS2
C   DETERMINE SOIL FORCE IF SKIN DEFLECTS TO ITS PREVIOUS EQUILIBRIUM POS
C     ITION.(YB2RIO(J))ASSUME VELOCITY AND POSITION CHANGE OF PT.IN MOVI
C     NG THRU DELS1 IS NEGLIGIBLE.
      CALL SOILRI(YB2ROI,YB2ROI,AREAR,FVROI,YB2DR,ZB2RSI,XB2RSI,ZB2DR,
     1XB2DR,YB2RIA,VECTBI)
      ACSAB1=(FDXR*XB2RSN(J)+FVTR*YB2RSN(J)+FDZR*ZB2RSN(J))/(VECTBN(J)*
     1FSRI)
      FPRL1=(-FSRI)*ACSAB1
      IF(FPRL1)8,8,9
    8 FPRL1=0.0
      NII=1
      GO TO 10
    9 NII=2
      GO TO 10
    7 DELS1=ABS(((FVRIO(J)*11.0447/(BOFF*AREAR))*ABS(YB2RIO(J)-YB2RI(J)
     1))/COTHTO)
      NII=1
   10 CALL GRSTEQ(NII,DELS1,FPRI,RIRX,RIRY,FPRL1,DELSM1,DELEQ1)
      YB2RI(J)=YB2RI(J)+ABS(DELEQ1*COTHTO)
      DELEQU(J)=DELEQ1
 6000 GO TO 1
    3 YB2RI(J)=0.0
      IF(NTEGER(I))6002,1,1
 6002 DELEQU(J)=0.0
    1 CONTINUE
C   EITHER GR.-ST.EQUILIBRIUM VALUES OF YB2RI(J) HAVE BEEN DETERMINED OR
C     ELSE YB2RI(J) HAS BEEN SET TO ZERO.ALL 72 J VALUES HAVE BEEN CONSI
C     DERED.USE THESE VALUES TO DETERMINE GROUND FORCES AND TORQUES ON
C     BODY 1.
      DO 21 J=1,72
      IF(YB2RI(J))22,21,21
   22 VELIR=Y(5)-OMZ1*P(J+6635)+OMY1*P(J+6707)
      VELJR=Y(6)-OMX1*P(J+6707)+OMZ1*P(J+6563)
      VELKR=Y(7)+OMX1*P(J+6635)-OMY1*P(J+6563)
      XB2DR=A1*VELIR+D1*VELJR+G1*VELKR
      YB2DR=B1*VELIR+E1*VELJR+H1*VELKR
      ZB2DR=C1*VELIR+F1*VELJR+AI1*VELKR
      YB2RIA=YB2RSN(J)
      VECTBI=VECTBN(J)
      ZB2RSI=ZB2RSN(J)
      XB2RSI=XB2RSN(J)
      FVROI=FVRIO(J)
      IF(J-24)23,23,24
   23 AREAR=P(6561)
      GO TO 27
   24 IF(J-48)25,25,26
   25 AREAR=P(6562)
      GO TO 27
   26 AREAR=P(6563)
   27 YB2ROI=YB2RIO(J)
      YB2IR=YB2RI(J)
      CALL SOILRI(YB2IR,YB2ROI,AREAR,FVROI,YB2DR,ZB2RSI,XB2RSI,ZB2DR,XB2
     1DR,YB2RIA,VECTBI)
C   TRANSFORM GROUND FORCES FROM INERTIAL AXES TO BODY 1 AXES
      FDX1R=A1*FDXR+B1*FVTR+C1*FDZR
      FVT1R=D1*FDXR+E1*FVTR+F1*FDZR
      FDZ1R=G1*FDXR+H1*FVTR+AI1*FDZR
```

```
C  COMPUTE TOTAL FORCES AND TORQUES ON BODY1 DUE TO GROUND-RING INTERACTION
      P(6999)=P(6999)+FDX1R
      P(7000)=P(7000)+FVT1R
      P(7001)=P(7001)+FDZ1R
      P(7002)=P(7002)+FDZ1R*P(J+6635)-FVT1R*P(J+6707)
      P(7003)=P(7003)-FDZ1R*P(J+6563)+FDX1R*P(J+6707)
      P(7004)=P(7004)+FVT1R*P(J+6563)-FDX1R*P(J+6635)
   21 CONTINUE
      RETURN
      END
```

SRC18

```
      SUBROUTINE SOILRI(YB2RI,YB2RIO,AREAR,FVRO,YB2DRI,ZB2RSI,XB2RSI,
     1ZB2DRI,XB2DRI,YB2RSI,VECTBI)
      DIMENSION P(9549),VAR(9999)
      COMMON VAR
      EQUIVALENCE(VAR(451),P(1)),(P(6000),ANG),(P(3964),AKC),(P(3958),
     1CGO),(P(3960),DENSTY),(P(3959),CDU),(P(3961),GCONST),(P(3962),GP
     2OWER),(P(3963),BOFF),(P(3965),AKNT),(P(3966),AMU),(P(7005),FSRI),
     3(P(7006),FVTR),(P(7007),FDZR),(P(7008),FDXR),(P(5936),THIO)
      IF(YB2RI-YB2RIO)1,1,2
    1 FVS=(GCONST*AREAR*(-YB2RI)**GPOWER)/11.0447
      GO TO 3
    2 FVS=FVRO+BOFF*(YB2RIO-YB2RI)*AREAR/11.0447
      IF(FVS)4,4,5
    4 FVS=0.0
      GO TO 5
    3 IF(YB2DRI)10,11,11
   11 FDYNA=0.0
      GO TO 6
   10 DYNAM=0.5*DENSTY*AREAR*AKC*YB2DRI**2
      CONE=AKNT*(-YB2RI)*AREAR/11.0447
      IF(CONE-DYNAM)7,7,8
    7 FDYNA=CONE
      GO TO 6
    8 FDYNA=DYNAM
    6 FVTR=FVS+FDYNA
      GO TO 9
    5 FVTR=FVS
C  CHECK FOR DRAG FORCE ON THE PAD
    9 IF(FVS)13,13,14
   13 AF=0.0
      GO TO 12
   14 GAMMA=ATAN2(ZB2RSI,XB2RSI)
      BEE=ATAN2(ZB2DRI,XB2DRI)
      GRAA=GAMMA-BEE
      IF(XB2RSI)15,16,16
   15 IF(ZB2RSI)17,18,19
C  IN THIRD QUADRANT
   17 IF(GRAA+4.7122)20,20,16
   20 GRAA=GRAA+6.28318
      GO TO 16
C  IN FORTH QUADRANT
   19 IF(GRAA-4.7122)16,21,21
   21 GRAA=GRAA-6.28318
      GO TO 16
   18 WRITE(6,22)
   22 FORMAT( 81H CANT TELL IF THIS RING POINT IS IN QUADRANT 3 OR 4.ASS
     1UME DRAG IS 0 AND CONTINUE)
```

```
   16 CONTINUE
      THTO=ARCOS(ABS(YB2RSI)/VECTBI)
C  CHECK DRAG FORCE CONDITION
      IF(ABS(GRAA)-1.5707)23,13,13
C  HAVE DRAG FORCE
C  ASSUME AREA ASSIGNED TO GIVEN POINT IS SQUARE AND COMPUTE SIDE OF IT
   23 ACSIDE=SQRT(AREAR)
      WPA=ACSIDE*COS(GRAA)
      HPA=ACSIDE*SIN(THTO)
C  COMPUTE FRONTAL(PROJECTED)AREA OF POINT
      AF=HPA*WPA
   12 FD1=CDO*DENSTY*(-YB2RI)*AF*ANG
      FD2=CDO*DENSTY*AF*(XB2DRI**2+ZB2DRI**2)
      FD=FD1+FD2+AMU*FVTR
      TVB2SI=SQRT(XB2DRI**2+ZB2DRI**2)
C  RESOLVE DRAG FORCE INTO INERTIAL X AND Z COMPONENTS
      FDXR=(-FD)*XB2DRI/TVB2SI
      FDZR=(-FD)*ZB2DRI/TVB2SI
      FSRI=SQRT(FDXR**2+FDZR**2+FVTR**2)
      RETURN
      END
```

SRC19

```
      SUBROUTINE GRSTEQ(NI,DELSI,FPRI,RIRX,RIRY,FPRLI,DELSMI,DELEQI)
      GO TO(1,2),NI
    1 XI=(FPRI*RIRX*DELSI)/(RIRY*DELSI+FPRI*RIRX)
      YI=RIRY*XI/RIRX
      IF(RIRY-YI)3,4,4
    3 XI=(FPRI-RIRY)*DELSI/FPRI
    4 DELEQI=XI
      GO TO 15
    2 IF(FPRI-FPRLI)5,5,6
    5 WRITE (6,7)
    7 FORMAT(120H CANNOT COMPUTE GR.-ST.EQUILIB.PT.FOR THIS RING PT. BEC
     1AUSE FPRLI IS GREATER THAN FPRI.ASSUME RIGID STRUCTURE AT THIS PT)
      DELEQI=0.0
      GO TO 15
    6 XI=(FPRI*RIRX*DELSI)/(RIRY*DELSI-RIRX*(FPRLI-FPRI))
      YI=RIRY*XI/RIRX
      IF(RIRY-YI)8,9,9
    9 IF(YI-FPRLI)10,4,4
   10 XI=FPRLI*DELSMI*RIRX/(RIRY*(DELSMI-DELSI)+FPRLI*RIRX)
      GO TO 4
    8 IF(FPRLI-RIRY)11,11,12
   11 XI=(RIRY-FPRI)*DELSI/(FPRLI-FPRI)
      GO TO 4
   12 YI=FPRLI*DELSMI*RIRY/(RIRY*(DELSMI-DELSI)+FPRLI*RIRX)
      IF(RIRY-YI)13,14,14
   14 XI=RIRX*YI/RIRY
      GO TO 4
   13 XI=(RIRY*(DELSI-DELSMI)/FPRLI)+DELSMI
      GO TO 4
   15 RETURN
      END
```

SRFO

```
      SUBROUTINE FILM(NN)
      DIMENSION T( 500),S2( 500),S3( 500),S4( 500),S5( 500),S6( 500),
     1S7( 500),HF2( 500),HF3( 500),HF4( 500),HF5( 500),HF6( 500),HF7(
     2 500),TF2( 500),TF3( 500),TF4( 500),TF5( 500),TF6( 500),TF7( 500)
     3,SR( 500),SL( 500),FR( 500),FL( 500),XB21( 500),YB21( 500),ZB21
     4( 500),AJ1( 500),AJ2( 500),TA1( 500),TA2( 500),REC(39)
      DIMENSION O1(12),O2(12),O3(12),O4(12),O5(12),O6(12),O7(12)
     1,O8(12),O9(12),O10(12),O11(12),O12(12),O13(12),O14(12),A2(12),
     2A3(12),A4(12),A5(12),A6(12),A7(12),A8(12)
      DIMENSION O15(12),O16(12),O17(12),O18(12),O19(12),O20(12),O21(12),
     1O22(12),O23(12)
      DIMENSION X1D( 500),OX1( 500),TH1( 500),Y1D( 500),OY1( 500),
     1PH1( 500),Z1D( 500),OZ1( 500),PS1( 500)
      REWIND 9
      NOUT=0
    2 IF(NN-500)3,3,4
    3 N=NN
      NOUT=1
      GO TO 5
    4 N=500
      NN=NN-500
    5 DO 1 J=1,N
      READ(9)(REC(I),I=1,39)
      T     (J)=REC(1 )
      S2   (J)=REC(2 )
      S3   (J)=REC(3 )
      S4   (J)=REC(4 )
      S5   (J)=REC(5 )
      S6   (J)=REC(6 )
      S7   (J)=REC(7 )
      HF2  (J)=REC(8 )
      HF3  (J)=REC(9 )
      HF4  (J)=REC(10)
      HF5  (J)=REC(11)
      HF6  (J)=REC(12)
      HF7  (J)=REC(13)
      TF2  (J)=REC(14)
      TF3  (J)=REC(15)
      TF4  (J)=REC(16)
      TF5  (J)=REC(17)
      TF6  (J)=REC(18)
      TF7  (J)=REC(19)
      SR   (J)=REC(20)
      SL   (J)=REC(21)
      FR   (J)=REC(22)
      FL   (J)=REC(23)
      XB21(J)=REC(24)
      YB21(J)=REC(25)
      ZB21(J)=REC(26)
      AJ1(J)=REC(27)/386.09
      AJ2(J)=REC(28)/386.09
      TA1(J)=REC(29)/386.09
      TA2(J)=REC(30)/386.09
      X1D(J)=REC(31)
      OX1(J)=REC(32)/386.09
      TH1(J)=REC(33)
      Y1D(J)=REC(34)
      OY1(J)=REC(35)/386.09
      PH1(J)=REC(36)
```

```
      ZID(J)=REC(37)
      UZI(J)=REC(38)/386.09
      PSI(J)=REC(39)
    1 CONTINUE
      DATA A2/72HTIME(SEC)....THIS CURVE FOR STRUT 2
     1                  /
      DATA A3/72HTIME(SEC)....THIS CURVE FOR STRUT 3
     1                  /
      DATA A4/72HTIME(SEC)....THIS CURVE FOR STRUT 4
     1                  /
      DATA A5/72HTIME(SEC)....THIS CURVE FOR STRUT 5
     1                  /
      DATA A6/72HTIME(SEC)....THIS CURVE FOR STRUT 6
     1                  /
      DATA A7/72HTIME(SEC)....THIS CURVE FOR STRUT 7
     1                  /
      DATA U1/72HSTRUT STROKE-IN-
     1                  /
      DATA U2/72HSTRUT H.C.FORCE-LB-
     1                  /
      DATA U3/72HSTRUT TOTAL FORCE-LB-
     1                  /
      DATA A8/72HTIME(SEC)
     1                  /
      DATA U4/72HRIGHT SIDE STRUT STROKE-INCHES-
     1                  /
      DATA U5/72HLEFT SIDE STRUT STROKE-INCHES-
     1                  /
      DATA U6/72HRIGHT SIDE STRUT FORCE-LB-
     1                  /
      DATA U7/72HLEFT SIDE STRUT FORCE-LB-
     1                  /
      DATA U8/72HXBAR2 TO C.G.1-IN-
     1                  /
      DATA U9/72HYBAR2 TO C.G.1-IN-
     1                  /
      DATA U10/72HZBAR2 TO C.G.1-IN-
     1                  /
      DATA U11/72HK1 COMP OF CG1 ABS ACCEL-G-
     1                  /
      DATA U12/72HJ1 COMP OF CG1 ABS ACCEL-G-
     1                  /
      DATA U13/72HSHELL TRANS.ACC.-G-
     1                  /
      DATA U14/72HCOUCH TRANS.ACC.-G-
     1                  /
      DATA U15/72HINERTIALXID-IN/SEC-
     1                  /
      DATA U16/72HINERTIALYID-IN/SEC-
     1                  /
      DATA U17/72HINERTIALZID-IN/SEC-
     1                  /
      DATA U18/72HI2 COMP OF AMETER-G-
     1                  /
      DATA U19/72HJ2 COMP OF AMETER-G-
     1                  /
      DATA U20/72HK2 COMP OF AMETER-G-
     1                  /
      DATA U21/72HTHI-DEG-
     1                  /
      DATA U22/72HPHI-DEG-
     1                  /
      DATA U23/72HPSI-DEG-
```

```
      CALL QUIKMV(-3,1H.,A2,01,-N,T(1),S2(1))
      CALL QUIKMV( 2,1H.,A2,02,-N,T(1),HF2(1))
      CALL QUIKMV( 3,1H.,A2,03,-N,T(1),TF2(1))
      CALL QUIKMV(-3,1H.,A3,01,-N,T(1),S3(1))
      CALL QUIKMV( 2,1H.,A3,02,-N,T(1),HF3(1))
      CALL QUIKMV( 3,1H.,A3,03,-N,T(1),TF3(1))
      CALL QUIKMV(-3,1H.,A4,01,-N,T(1),S4(1))
      CALL QUIKMV( 2,1H.,A4,02,-N,T(1),HF4(1))
      CALL QUIKMV( 3,1H.,A4,03,-N,T(1),TF4(1))
      CALL QUIKMV(-3,1H.,A5,01,-N,T(1),S5(1))
      CALL QUIKMV( 2,1H.,A5,02,-N,T(1),HF5(1))
      CALL QUIKMV( 3,1H.,A5,03,-N,T(1),TF5(1))
      CALL QUIKMV(-3,1H.,A6,01,-N,T(1),S6(1))
      CALL QUIKMV( 2,1H.,A6,02,-N,T(1),HF6(1))
      CALL QUIKMV( 3,1H.,A6,03,-N,T(1),TF6(1))
      CALL QUIKMV(-3,1H.,A7,01,-N,T(1),S7(1))
      CALL QUIKMV( 2,1H.,A7,02,-N,T(1),HF7(1))
      CALL QUIKMV( 3,1H.,A7,03,-N,T(1),TF7(1))
      CALL QUIKMV(-2,1H.,A8,04,N,T(1),SR(1))
      CALL QUIKMV( 2,1H.,A8,06,N,T(1),FR(1))
      CALL QUIKMV(-2,1H.,A8,05,N,T(1),SL(1))
      CALL QUIKMV( 2,1H.,A8,07,N,T(1),FL(1))
      CALL QUIKMV(-3,1H.,A8,08,N,T(1),XB21(1))
      CALL QUIKMV( 2,1H.,A8,09,N,T(1),YB21(1))
      CALL QUIKMV( 3,1H.,A8,010,N,T(1),ZB21(1))
      CALL QUIKMV(-2,1H.,A8,011,-N,T(1),AJ1(1))
      CALL QUIKMV( 2,1H.,A8,012,-N,T(1),AJ2(1))
      CALL QUIKMV(-2,1H.,A8,013,-N,T(1),TA1(1))
      CALL QUIKMV( 2,1H.,A8,014,-N,T(1),TA2(1))
      CALL QUIKMV(-3,1H.,A8,015,N,T(1),X1D(1))
      CALL QUIKMV( 2,1H.,A8,016,N,T(1),Y1D(1))
      CALL QUIKMV( 3,1H.,A8,017,N,T(1),Z1D(1))
      CALL  QUIKMV(-3,1H.,A8,018,-N,T(1),OX1(1))
      CALL  QUIKMV( 2,1H.,A8,019,-N,T(1),OY1(1))
      CALL  QUIKMV( 3,1H.,A8,020,-N,T(1),OZ1(1))
      CALL QUIKMV(-3,1H.,A8,021,N,T(1),TH1(1))
      CALL QUIKMV( 2,1H.,A8,022,N,T(1),PH1(1))
      CALL QUIKMV( 3,1H.,A8,023,N,T(1),PS1(1))
      IF(NOUT)2,2,6
    6 RETURN
      END
```

APPENDIX B

COMPUTER-PROGRAM DATA AND CORRELATION STUDY

In this appendix, the computer-program input and output data are described. A sample problem is included to provide a comparison between computer-predicted results and actual test results.

COMPUTER-PROGRAM INPUT

The computer-program input, including format and ordering, is described in this section. The following fixed-point data should be punched on a single data card in the order given. This card should be the first card in the data deck and must be included each time a stacked run is made. The card codes and inputs are punched in FORMAT (915).

Card code	Input
1 or -1	Code number indicating the desired loading option for the edge rings. The integer "1" is used for rigid edge rings, and the integer "-1" is used for deformable edge rings.
Integer value 6	Number of floating-point values to be input on cards. Number of auxiliary differential equations (control equations, etc.) to be integrated in the Runge-Kutta subroutine. This number is now 6 and may not exceed 18.
Integer $\leq$ 19	N; the two lateral attenuation struts (couch bumpers parallel to the i_2-axis) are not included.
Integer $\leq$ 200	NSK; bolt-circle points are not included.
Integer $\leq$ 19	N_{SS}
1 or 0	S-C 4020 output-option code number. The integer "1" calls for 14 graphs to be output; the integer "0" omits the graphs.
Integer $\leq$ 50	NBC
1, 0, or -1	Code number indicating the desired integration routine. The integer "1" is used for the variable-step Adams-Moulton routine. (This mode will work only if the two bodies are connected exclusively with spring-damper shocks.) The integer "0" is used for the fixed-step Adams-Moulton routine, and the integer "-1" is used for the fixed-step Runge-Kutta routine. (This mode should be used for Apollo landing studies.)

Each line of the following data should be punched on a single card in FORMAT (I5, E 15.0). Data which have a value of zero may be ignored. The order of these cards in the data deck is unimportant. Much of the following data will remain constant from run to run and can be loaded on an auxiliary data tape to facilitate card handling. This procedure will be explained following the data listing.

Identification number	Input variable	Remarks
1	Integration step size, sec	
2	Program termination time, sec	
3	$I_{i',1}$	
4	$I_{j',1}$	
5	$I_{k',1}$	
6	M_1	
7	Output data step size, sec	
9	Program start time, sec	
10	$\bar{i}_1 \cdot \bar{i}_1'$	Direction cosines for body 1.
11	$\bar{i}_1 \cdot \bar{j}_1'$	
12	$\bar{i}_1 \cdot \bar{k}_1'$	
13	$\bar{j}_1 \cdot \bar{i}_1'$	
14	$\bar{j}_1 \cdot \bar{j}_1'$	
15	$\bar{j}_1 \cdot \bar{k}_1'$	
16	$\bar{k}_1 \cdot \bar{i}_1'$	
17	$\bar{k}_1 \cdot \bar{j}_1'$	
18	$\bar{k}_1 \cdot \bar{k}_1'$	
19	$I_{i',2}$	
20	$I_{j',2}$	
21	$I_{k',2}$	
22	M_2	

Identification number	Input variable	Remarks
23	A1	Nonzero only when the variable-step Adams-Moulton integration routine is used.
24	A2	
25	A3	
26	$\bar{i}_2 \cdot \bar{i}'_2$	Direction cosines for body 2.
27	$\bar{i}_2 \cdot \bar{j}'_2$	
28	$\bar{i}_2 \cdot \bar{k}'_2$	
29	$\bar{j}_2 \cdot \bar{i}'_2$	
30	$\bar{j}_2 \cdot \bar{j}'_2$	
31	$\bar{j}_2 \cdot \bar{k}'_2$	
32	$\bar{k}_2 \cdot \bar{i}'_2$	
33	$\bar{k}_2 \cdot \bar{j}'_2$	
34	$\bar{k}_2 \cdot \bar{k}'_2$	
104	A4	Nonzero only when the variable-step Adams-Moulton integration routine is used.
105	A5	
106	A7	
110	V_T, fps	Temporary values at input time only (must be included each time a stacked run is made).
111	V_N, fps	
112	Φ, deg	
113	θ_1	
114	ϕ_1	
115	ψ_1	

Identification number	Input variable	Remarks
		The lowest subscripts must refer to the spring shocks, if any. That is,
143	X_2	X_{2}, Y_{2}, Z_{2} ⋮ $X_{n,SS+1}, Y_{n,SS+1}, Z_{n,SS+1}$ — Spring shocks (ignore if $N_{SS} = 0$).
144	Y_2	
145	Z_2	
⋮	⋮	$X_{n,SS+2}, Y_{n,SS+2}, Z_{n,SS+2}$ ⋮ $X_{n+1}, Y_{n+1}, Z_{n+1}$ — Honeycomb or cyclic-deformation shocks (ignore if $N = N_{SS}$; do not include lateral struts).
140 + 3N	X_{N+1}	
141 + 3N	Y_{N+1}	
142 + 3N	Z_{N+1}	
222	$X_{p,1,2}$	
⋮	⋮	
221 + N	$X_{p,1,N+1}$	
242	$Y_{p,1,2}$	
⋮	⋮	
241 + N	$Y_{p,1,N+1}$	
119	u''_2	Zeros were input for the CM correlation study. The computer program requires the same values for body 1 and body 2.
120	v''_2	
121	w''_2	
122	θ_2	
123	ϕ_2	
124	ψ_2	
125	$G_{\bar{\bar{X}}}$	
126	$G_{\bar{\bar{Y}}}$	
127	$G_{\bar{\bar{Z}}}$	

Identification number	Input variable	Remarks
140	X_1	Components from $c.g._1$ to $c.g._2$.
141	Y_1	
142	Z_1	
262 ⋮ 261 + N	$Z_{p,1,2}$ ⋮ $Z_{p,1,N+1}$	
282 ⋮ 281 + N	$X_{p,2,2}$ ⋮ $X_{p,2,N+1}$	
302 ⋮ 301 + N	$Y_{p,2,2}$ ⋮ $Y_{p,2,N+1}$	
322 ⋮ 321 + N	$Z_{p,2,2}$ ⋮ $Z_{p,2,N+1}$	
421 ⋮ 424	$X_{p,1+L}$ ⋮ $X_{p,1-L}$	
427	$X_{p,2+L}$	Coordinates of the tip of the unstroked lateral strut (right couch bumper).
428	$Y_{p,2+L}$	
429	$Z_{p,2+L}$	
430	$X_{p,2-L}$	Coordinates of the tip of the unstroked lateral strut (left couch bumper).
431	$Y_{p,2-L}$	
432	$Z_{p,2-L}$	
582 ⋮ 581 + N	CL_2 ⋮ CL_{N+1}	

Identification number	Input variable	Remarks
602 ⋮ $601 + N_{SS}$	CK_2 ⋮ $CK_{N, SS+1}$	Spring shocks (ignore if $N_{SS} = 0$).
622 ⋮	CD_2 ⋮	Spring shocks (ignore if $N_{SS} = 0$). When cyclic deformation is used, C_{ST} is punched instead of CD_2.
$621 + N_{SS}$	$CD_{N, SS+1}$	Spring shocks (ignore if $N_{SS} = 0$).
965 966 967	X_{AR} Y_{AR} Z_{AR}	X_{AR} and Z_{AR} must be equal to their corresponding values for a vector from c.g.$_1$ to point RC along the i_1- and k_1-axes, respectively.
968	X_{RC}	
970	$\Omega_{x, 1}$	
971	$\Omega_{y, 1}$	
972	$\Omega_{z, 1}$	
980	$\Omega_{x, 2}$	
981	$\Omega_{y, 2}$	
982	$\Omega_{z, 2}$	
983 ⋮ 982 + NSK	$X_{S, 1, 1}$ ⋮ $X_{S, 1, NSK}$	
1183 ⋮ 1182 + NSK	$Y_{S, 1, 1}$ ⋮ $Y_{S, 1, NSK}$	
1383 ⋮ 1382 + NSK	$Z_{S, 1, 1}$ ⋮ $Z_{S, 1, NSK}$	

Identification number	Input variable	Remarks
2743	SC1S	
2744	BKC1S	Couch-bumper shocks; positive sign.
2745	EL1CS	
2746	AKPS	
2747	SEVC3P	Couch-bumper shock; negative sign.
2748	SEVC3M	Couch-bumper shock; positive sign.
2749	FEC13P	Couch-bumper shock; negative sign.
2750	FEC13M	Couch-bumper shock; positive sign.
3958	CGO	
3959	CDO	
3960	DENSTY	
3961	GCØNST	
3962	GPOWER	
3963	BOFF	
3964	AKC	
3965	AKNT	
3966	AMU	
3967	FA	
5180	t_1	
⋮	⋮	
5179 + (NSK + NBC)	$t_{NSK+NBC}$	
5930	XR	
5931	HEATB	
5935	ARS1	
5936	ARS2	

Identification number	Input variable	Remarks
2184	$EL1T_{N, SS+2}$	
⋮	⋮	
$2183 + (N - N_{SS})$	$EL1T_{N+1}$	
2204	$ST1_{N, SS+2}$	
⋮	⋮	
$2203 + (N - N_{SS})$	$ST1_{N+1}$	
2224	$EL1C_{N, SS+2}$	
⋮	⋮	
$2223 + (N - N_{SS})$	$EL1C_{N+1}$	
2244	$SC1_{N, SS+2}$	
⋮	⋮	
$2243 + (N - N_{SS})$	$SC1_{N+1}$	
2264	$ST2_{N, SS+2}$	
⋮	⋮	
$2263 + (N - N_{SS})$	$ST2_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); positive sign.
2284	$EL3T_{N, SS+2}$	
⋮	⋮	
$2283 + (N - N_{SS})$	$EL3T_{N+1}$	
2304	$EL2T_{N, SS+2}$	
⋮	⋮	
$2303 + (N - N_{SS})$	$EL2T_{N+1}$	
2324	$SC2_{N, SS+2}$	
⋮	⋮	
$2323 + (N - N_{SS})$	$SC2_{N+1}$	
2344	$EL3C_{N, SS+2}$	
⋮	⋮	
$2343 + (N - N_{SS})$	$EL3C_{N+1}$	
2364	$EL2C_{N, SS+2}$	
⋮	⋮	
$2363 + N - N_{SS})$	$EL2C_{N+1}$	
2384	$AKT_{N, SS+2}$	
⋮	⋮	
$2383 + (N - N_{SS})$	AKT_{N+1}	

Identification number	Input variable	Remarks
2404 ⋮ $2403 + (N - N_{SS})$	$AKP_{N, SS+2}$ ⋮ AKP_{N+1}	Honeycomb shocks (ignore if $N - N_{SS} = 0$); positive sign.
2424 ⋮ $2423 + (N - N_{SS})$	$SEVT3_{N, SS+2}$ ⋮ $SEVT3_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); positive sign. Initial conditions; ignore if the shocks are in the equilibrium position.
2444 ⋮ $2443 + (N - N_{SS})$	$SEVC3_{N, SS+2}$ ⋮ $SEVC3_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); negative sign. Initial conditions; ignore if the shocks are in the equilibrium position.
2464 ⋮ $2463 + (N - N_{SS})$	$FEM13S_{N, SS+2}$ ⋮ $FEM13S_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); positive sign. Initial conditions; ignore if the shocks are in the equilibrium position.
2624 ⋮ $2623 + (N - N_{SS})$	$FEC13S_{N, SS+2}$ ⋮ $FEC13S_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); negative sign. Initial conditions; ignore if the shocks are in the equilibrium position.
2664 ⋮ $2663 + (N - N_{SS})$	$FFNSP_{N, SS+2}$ ⋮ $FFNSP_{N+1}$	Honeycomb shocks (ignore if $N - N_{SS} = 0$); positive sign.
2684 ⋮ $2683 + (N - N_{SS})$	$FFNSN_{N, SS+2}$ ⋮ $FFNSN_{N+1}$	
2704 ⋮ $2703 + (N - N_{SS})$	$FFPSP_{N, SS+2}$ ⋮ $FFPSP_{N+1}$	
2724 ⋮ $2723 + (N - N_{SS})$	$FFPSN_{N, SS+2}$ ⋮ $FFPSN_{N+1}$	

Identification number	Input variable	Remarks
5937	ARS3	
5939	hh	
5940	NOOR	Must be less than or equal to 20.
5941	NOTHT	Must be less than or equal to 40.
5942	LBC	
5943	E	Must be 31.818×10^6.
5944	ν	
5992	$\bar{\bar{X}}_1$	
5994	$\bar{\bar{Z}}_1$	
5995	$\bar{\bar{X}}_2$	
6501	ϕ_1	
$\vdots$	$\vdots$	
6500 + NOTHT	ϕ_{NOTHT}	
6541	r_1	
$\vdots$	$\vdots$	
6540 + NOOR	r_{NOOR}	
6561	AREA1	
6562	AREA2	
6563	AREA3	
7009	FR1	Must be greater than 0.0.
7010	DR1	
7011	FR2	Must be greater than 0.0.
7012	DR2	
7013	FR3	
7014	DR3	

Identification number	Input variable	Remarks
7015	$X_{S,1,RS1,1}$	
⋮	⋮	
⋮	$X_{S,1,RS1,24}$	
⋮	$X_{S,1,RS2,1}$	
⋮	⋮	
⋮	$X_{S,1,RS2,24}$	
⋮	$X_{S,1,RS3,1}$	
⋮	⋮	
7086	$X_{S,1,RS3,24}$	
7087	$Y_{S,1,RS1,1}$	
⋮	⋮	
⋮	$Y_{S,1,RS1,24}$	
⋮	$Y_{S,1,RS2,1}$	Points on the edge rings must be numbered as indicated in figure 13.
⋮	⋮	
⋮	$Y_{S,1,RS2,24}$	
⋮	$Y_{S,1,RS3,1}$	
⋮	⋮	
7158	$Y_{S,1,RS3,24}$	
7159	$Z_{S,1,RS1,1}$	
⋮	⋮	
⋮	$Z_{S,1,RS1,24}$	
⋮	$Z_{S,1,RS2,1}$	
⋮	⋮	
⋮	$Z_{S,1,RS2,24}$	
⋮	$Z_{S,1,RS3,1}$	
⋮	⋮	
7230	$Z_{S,1,RS3,24}$	
7666	$ACCEL_{2,i,2}$	
7667	$ACCEL_{2,j,2}$	
7668	$ACCEL_{2,k,2}$	

To facilitate data handling, any of the preceding floating-point data may be stored on tape by using an auxiliary program similar to that given in the section of this appendix entitled "Auxiliary Program for Storing Data on Tape." Note that the data tape in this case is defined to be scratch tape 13. The tape includes data for the Weber couch and data for a particular set of cyclic-deformation struts. The tape has been retained in the NASA Manned Spacecraft Center tape library and is available for use on any subsequent runs. The integers used to identify the data are stored in the N array, beginning with N(29) = 3. The corresponding data are stored in the P array, such that the P subscript is equal to the N subscript. If, for example, the value of M_1 is to be changed from 29.066 to 30.0, then card 5 must be changed to P(32) = 30.0. The computer program can then be executed, and a new data tape will be generated.

The data tape is read into the computer for each computer run made (stacked or single). Each computer run will have regular card-input data. Any data on the tape that are to be changed for a particular computer run may simply be included in the card input for that run. These card data will replace the corresponding tape-data items for that computer run only, not for any succeeding stacked runs.

A new tape may be required to incorporate changes in the data. If a new tape is needed, the desired changes can be implemented as follows. Input data which are not on the current data tape include items 1, 2, 7, 9, 11, 12, 13, 15, 16, 17, 27, 28, 29, 31, 32, 33, 110 to 115, 125, 126, 127, 970, 971, 972, 980, 981, 982, 2424 to 2643, 2747 to 2750, 3958, 3959, 5930, 5931, 5992, 5994, 5995, 7666, 7667, and 7668. These data must be entered on cards. Any data that do not change for stacked runs may be entered only at the first run, with the exceptions of items 110, 111, and 112, which are entered each time. Zero values need not be included in the data cards.

To summarize, data for the first of a series of computer runs must include either a card or a value on the data tape for all nonzero floating-point parameters, as well as the card of fixed-point data. Card data for succeeding runs may omit any nonzero floating-point data (other than items 110, 111, and 112) which remain unchanged from the preceding run. Changes in tape data are entered on cards with each computer run, along with the fixed-point-data card.

COMPUTER PROGRAM OUTPUT

Table B-I provides a key to the computer-program-output symbology. Time histories of the first 68 dependent variables (X1DD to NPR3 in table B-I) will be produced by the system printer for each computer run made. In addition to this fixed-output format, an optional form of output is available through the use of the high-speed microfilm recorder. This option is controlled by the seventh fixed-point number on the first data card of each run and consists of 14 data graphs of special interest. (See the section of this appendix entitled "Computer Program Input.")

The stability angle SANG (fig. B-1) is computed by the computer program at each time step. The computer program first establishes plane R, which contains the inertial horizontal velocity vector and the gravity vector G. Next, the location of point P is determined. The vehicle is considered to be unstable if G falls outside of P (if $\beta < 0$). If R does not intersect the heat-shield rim, point P does not exist, and the vehicle is unstable in a lateral toppling mode.

SAMPLE PROBLEM

The data used for the sample problem were taken from the Apollo command module 009 drop test (NASA Manned Spacecraft Center impact test number 31, March 7, 1968). Initial conditions and axis orientation are shown in figure B-2. The input data for the run and the data which were read from the data tape are given in table B-II. All other data were read from cards. The pattern of points used on the heat shield is shown in figure B-3. A sheet of printed output is shown in figure B-4, and 14 microfilm-recorder graphs are shown in figures B-5 to B-18. The computer results for struts 2 to 5 indicated that strokes were less than 0.14 inch, or below the sensitivity of the drop-test instrumentation. Because the test data indicated zero strokes for these struts, the computer results may be considered to have correlated with the test results for struts 2 to 5. The test results for struts 6 and 7 are superimposed on the appropriate portions of the computer output (figs. B-9 and B-10) to indicate the degree of correlation between the simulated impact and the actual test. Figure B-14 compares measured values of certain absolute acceleration components (j_1 and k_1 of $c.g._1$) with the values predicted in the computer output.

AUXILIARY PROGRAM FOR STORING DATA ON TAPE

This section is the auxiliary program for storing the floating-point data on tape. To minimize the number of pages in this report, two pages of computer listing are shown on each page of this section. To properly order the listing, the right column should follow the left column.

```
      DIMENSION P(1307),N(1307)
      P( 29)= 60276.0
      P( 30)= 68700.0
      P( 31)= 54096.0
      P( 32)= 29.066
      P(  33)= .10000000E1
      P(  34)= .10000000E1
      P(  35)= .10000000E1
      P( 36)= 454.0
      P( 37)= 1379.0
      P( 38)= 1134.0
      P( 39)= 2.569
      P(  40)= .10000000E1
      P(  41)= .10000000E1
      P(  42)= .10000000E1
      P( 43)=-1.4
      P( 44)= 5.3
      P( 45)= 18.5
      P( 46)= .979
      P( 47)=-36.195
      P( 48)= 5.537
      P( 49)=-.979
      P( 50)=-36.195
      P( 51)= 5.537
      P( 52)= 1.894
      P( 53)=-33.961
      P( 54)= .8814
      P( 55)=-1.894
      P( 56)=-33.961
      P( 57)= .8814
      P( 58)= .379
      P( 59)= 14.493
      P( 60)=-36.289
      P( 61)=-.379
      P( 62)= 14.493
      P( 63)=-36.289
      P( 64)=-14.2290
      P( 65)= 14.2290
      P( 66)=-14.1430
      P( 67)= 14.1430
      P( 68)= -12.632
      P( 69)= 12.6320
      P( 70)=35.23700
      P( 71)=35.23700
      P( 72)=42.61300
      P( 73)=42.61300
      P( 74)=-22.2000
      P( 75)=-22.2000
      P( 76)=41.06900
      P( 77)=41.06900
      P( 78)=-6.47600
      P( 79)=-6.47600
      P( 80)=60.85000
      P( 81)=60.85000
      P( 82)=-11.85
      P( 83)= 14.65
      P( 84)=-10.85
      P( 85)= 13.65
      P( 86)=-10.85
      P( 87)= 13.65
      P( 88)=-6.258
      P( 89)=-6.258
      P( 90)= 3.353
      P( 91)= 3.353
      P( 92)=-13.007
      P( 93)=-13.007
      P( 94)= 28.1
      P( 95)= 28.1
      P( 96)=-24.095
      P( 97)=-24.095
      P( 98)= 6.062
      P( 99)= 6.062
      P(100)=42.00000
      P(101)=-42.0000
      P(102)= 43.4
      P(103)=-11.288
      P(104)=-9.12
      P(105)=-40.6
      P(106)=-11.288
      P(107)=-9.12
      P(108)= 36.629
      P(109)= 36.629
      P(110)= 34.025
      P(111)= 34.025
      P(112)= 39.079
      P(113)= 39.079
      P(114)=0.000000
      P(115)=-37.2000
      P(116)=6.6
      P( 117)= .17640000E3
      P(118)=6625.000
      P( 119)= .16000000E5
      P(120)=.4140600
      P( 121)= .16000000E5
      P(122)=.1900000
```

```
P(123)=.1900000
P(124)=.2453000
P(125)=.2453000
P(126)=.2046000
P(127)=.2046000
P(128)=3040.000
P(129)=3040.000
P(130)=3924.000
P(131)=3924.000
P(131)=3924.0
P(132)=3274.000
P(133)=3274.000
P(134)=.1900000
P(135)=.1900000
P(136)=.2453000
P(137)=.2453000
P(138)=.2787000
P(139)=.2787000
P(140)=3040.000
P(141)=3040.000
P(142)=3924.000
P(143)=3924.000
P(144)=4459.000
P(145)=4459.000
P( 146)= .10000000E7
P( 147)= .10000000E7
P( 148)= .10000000E7
P( 149)= .10000000E7
P( 150)= .10000000E7
P( 151)= .10000000E7
P(152)=16.20000
P(153)=16.20000
P( 154)= .16200000E2
P( 155)= .16200000E2
P(156)=18.20000
P(157)=18.20000
P(158)=16.00000
P(159)=16.00000
P( 160)= .16000000E2
P( 161)= .16000000E2
P(162)=18.00000
P(163)=18.00000
P( 164)= .10000000E7
P( 165)= .10000000E7
P( 166)= .10000000E7
P( 167)= .10000000E7
P( 168)= .10000000E7
P( 169)= .10000000E7
P( 170)= .12000000E1
P( 171)= .12000000E1
P( 172)= .12000000E1
P( 173)= .12000000E1
P( 174)= .52000000E1
P( 175)= .52000000E1
P( 176)= .10000000E1
P( 177)= .10000000E1
P( 178)= .10000000E1
P( 179)= .10000000E1
P( 180)= .50000000E1
P( 181)= .50000000E1
P( 182)= .16000000E5
P( 183)= .16000000E5
P( 184)= .16000000E5
P( 185)= .16000000E5
P( 186)= .16000000E5
P( 187)= .16000000E5
P( 188)= .16000000E5
P( 189)= .16000000E5
P( 190)= .16000000E5
P( 191)= .16000000E5
P( 192)= .16000000E5
P( 193)= .16000000E5
P(194)=1470.000
P(195)=1470.000
P(196)=1540.000
P(197)=1540.000
P(198)=690.0000
P(199)=690.0000
P(200)=1470.000
P(201)=1470.000
P(202)=1540.000
P(203)=1540.000
P(204)=690.0000
P(205)=690.0000
P(206)=1470.000
P(207)=1470.000
P(208)=1540.000
P(209)=1540.000
P(210)=2500.000
P(211)=2500.000
P(212)=1470.000
P(213)=1470.000
P(214)=1540.000
P(215)=1540.000
P(216)=2500.000
```

```
P(217)=2500.000
P( 218)= .58400000E-1
P( 219)= .60000000E2
P( 220)= .37000000E0
P( 221)= .20000000E5
P( 222)= .17800000E2
P( 223)= .36000000E4
P( 224)= .25000000E0
P( 225)= .57585000E0
P( 226)=000.00
P( 227)=000.90
P( 228)=001.79
P( 229)=003.53
P( 230)=005.17
P( 231)=006.64
P( 232)=007.92
P( 233)=009.71
P( 234)=010.33
P( 235)=009.71
P( 236)=007.92
P( 237)=005.17
P( 238)=003.53
P( 239)=001.79
P( 240)=000.00
P( 241)=-01.79
P( 242)=-03.53
P( 243)=-05.17
P( 244)=-07.92
P( 245)=-09.71
P( 246)=-10.33
P( 247)=-09.71
P( 248)=-07.92
P( 249)=-06.64
P( 250)=-05.17
P( 251)= -3.53
P( 252)= -1.79
P( 253)= -0.90
P( 254)=000.00
P( 255)=  1.80
P( 256)=  3.59
P( 257)=  7.07
P( 258)= 10.33
P( 259)= 13.29
P( 260)= 15.83
P( 261)= 19.42
P( 262)= 20.67
P( 263)= 19.42
P( 264)= 15.83
P( 265)= 10.33
P( 266)=  7.07
P( 267)=  3.59
P( 268)=000.00
P( 269)= -3.59
P( 270)= -7.07
P( 271)=-10.33
P( 272)=-15.83
P( 273)=-19.42
P( 274)=-20.67
P( 277)=-13.29
P( 276)=-15.83
P( 275)=-19.42
P(278)=-10.33
P( 279)= -7.07
P(280)=-3.59
P( 281)= -1.80
P( 282)=000.00
P( 283)=  2.70
P( 284)=  5.38
P( 285)= 10.60
P( 286)= 15.50
P( 287)= 19.93
P( 288)= 23.75
P( 289)= 29.13
P( 290)= 31.00
P( 291)= 29.13
P( 292)= 23.75
P( 293)= 15.50
P( 294)= 10.60
P( 295)=  5.38
P( 296)=000.00
P( 297)= -5.38
P( 298)=-10.60
P( 299)=-15.50
P( 300)=-23.75
P( 301)=-29.13
P( 302)=-31.00
P( 303)=-29.13
P( 304)=-23.75
P( 305)=-19.93
P( 306)=-15.50
P( 307)=-10.60
P( 308)= -5.38
P( 309)= -2.70
P( 310)=000.00
P( 311)=  3.60
P( 312)=  7.18
```

P(313)= 14.14
P(314)= 20.67
P(315)= 26.57
P(316)= 31.67
P(317)= 38.84
P(318)= 41.34
P(319)= 38.84
P(320)= 31.67
P(321)= 20.67
P(322)= 14.14
P(323)= 7.18
P(324)=000.00
P(325)= -7.18
P(326)=-14.14
P(327)=-20.67
P(328)=-31.67
P(329)=-38.84
P(330)=-41.34
P(331)=-38.84
P(332)=-31.67
P(333)=-26.57
P(334)=-20.67
P(335)=-14.14
P(336)= -7.18
P(337)= -3.60
P(338)=000.00
P(339)= 4.50
P(340)= 8.97
P(341)= 17.67
P(342)= 25.84
P(343)= 33.21
P(344)= 39.58
P(345)= 48.55
P(346)= 51.67
P(347)= 48.55
P(348)= 39.58
P(349)= 25.84
P(350)= 17.67
P(351)= 8.97
P(352)=000.00
P(353)= -8.97
P(354)=-17.67
P(355)=-25.84
P(356)=-39.58
P(357)=-48.55
P(358)=-51.67
P(359)=-48.55
P(360)=-39.58
P(361)=-33.21
P(362)=-25.84
P(363)=-17.67
P(364)= -8.97
P(365)= -4.50
P(366)=000.00
P(367)= 5.76
P(368)= 11.49
P(369)= 22.50
P(370)= 33.07
P(371)= 42.51
P(372)= 50.67
P(373)= 62.15
P(374)= 66.14
P(375)= 62.15
P(376)= 50.67
P(377)= 33.07
P(378)= 22.50
P(379)= 11.49
P(380)= 00.00
P(381)=-11.49
P(382)=-22.50
P(383)=-33.07
P(384)=-50.67
P(385)=-62.15
P(386)=-66.14
P(387)=-62.15
P(388)=-50.67
P(389)=-42.51
P(390)=-33.07
P(391)=-22.50
P(392)=-11.49
P(393)= -5.76
P(394)=000.00
P(395)= 6.31
P(396)= 12.56
P(397)= 24.74
P(398)= 36.17
P(399)= 46.50
P(400)= 55.41
P(401)= 67.98
P(402)= 72.34
P(403)= 67.98
P(404)= 55.41
P(405)= 36.17
P(406)= 24.74
P(407)= 12.56
P(408)= 00.00
P(409)=-12.56
P(410)=-24.74
P(411)=-36.17

```
P( 412)=-55.41
P( 413)=-67.98
P( 414)=-72.34
P( 415)=-67.98
P( 416)=-55.41
P( 417)=-46.50
P( 418)=-36.17
P( 419)=-24.74
P( 420)=-12.56
P( 421)= -6.31
P( 422)=0.303
P( 423)=0.303
P( 424)=0.303
P( 425)=0.303
P( 426)=0.303
P( 427)=0.303
P( 428)=0.303
P( 429)=0.303
P( 430)=0.303
P( 431)=0.303
P( 432)=0.303
P( 433)=0.303
P( 434)=0.303
P( 435)=0.303
P( 436)=0.303
P( 437)=0.303
P( 438)=0.303
P( 439)=0.303
P( 440)=0.303
P( 441)=0.303
P( 442)=0.303
P( 443)=0.303
P( 444)=0.303
P( 445)=0.303
P( 446)=0.303
P( 447)=0.303
P( 448)=0.303
P( 449)=0.303
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P( 451)=1.214
P( 452)=1.214
P( 453)=1.214
P( 454)=1.214
P( 455)=1.214
P( 456)=1.214
P( 457)=1.214
P( 458)=1.214
P( 459)=1.214
P( 460)=1.214
P( 461)=1.214
P( 462)=1.214
P( 463)=1.214
P( 464)=1.214
P( 465)=1.214
P(466)=1.214
P( 467)=1.214
P( 468)=1.214
P( 469)=1.214
P( 470)=1.214
P( 471)=1.214
P( 472)=1.214
P( 473)=1.214
P( 474)=1.214
P( 475)=1.214
P( 476)=1.214
P( 477)=1.214
P( 478)=2.743
P( 479)=2.743
P( 480)=2.743
P( 481)=2.743
P( 482)=2.743
P( 483)=2.743
P( 484)=2.743
P( 485)=2.743
P( 486)=2.743
P( 487)=2.743
P( 488)=2.743
P( 489)=2.743
P( 490)=2.743
P( 491)=2.743
P( 492)=2.743
P( 493)=2.743
P( 494)=2.743
P( 495)=2.743
P( 496)=2.743
P( 497)=2.743
P( 498)=2.743
P( 499)=2.743
P( 500)=2.743
P( 501)=2.743
P( 502)=2.743
P( 503)=2.743
P( 504)=2.743
P( 505)=2.743
P( 506)=4.906
P( 507)=4.906
P( 508)=4.906
```

P(509)=4.906
P(510)=4.906
P(511)=4.906
P(512)=4.906
P(513)=4.906
P(514)=4.906
P(515)=4.906
P(516)=4.906
P(517)=4.906
P(518)=4.906
P(519)=4.906
P(520)=4.906
P(521)=4.906
P(522)=4.906
P(523)=4.906
P(524)=4.906
P(525)=4.906
P(526)=4.906
P(527)=4.906
P(528)=4.906
P(529)=4.906
P(530)=4.906
P(531)=4.906
P(532)=4.906
P(533)=4.906
P(534)=7.728
P(535)=7.728
P(536)=7.728
P(537)=7.728
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P(539)=7.728
P(540)=7.728
P(541)=7.728
P(542)=7.728
P(543)=7.728
P(544)=7.728
P(545)=7.728
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P(547)=7.728
P(548)=7.728
P(549)=7.728
P(550)=7.728
P(551)=7.728
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P(553)=7.728
P(554)=7.728
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P(557)=7.728
P(558)=7.728
P(559)=7.728
P(560)=7.728
P(561)=7.728
P(562)=12.85
P(563)=12.85
P(564)=12.85
P(565)=12.85
P(566)=12.85
P(567)=12.85
P(568)=12.85
P(569)=12.85
P(570)=12.85
P(571)=12.85
P(572)=12.85
P(573)=12.85
P(574)=12.85
P(575)=12.85
P(576)=12.85
P(577)=12.85
P(578)=12.85
P(579)=12.85
P(580)=12.85
P(581)=12.85
P(582)=12.85
P(583)=12.85
P(584)=12.85
P(585)=12.85
P(586)=12.85
P(587)=12.85
P(588)=12.85
P(589)=12.85
P(590)=15.50
P(591)=15.50
P(592)=15.50
P(593)=15.50
P(594)=15.50
P(595)=15.50
P(596)=15.50
P(597)=15.50
P(598)=15.50
P(599)=15.50
P(600)=15.50
P(601)=15.50
P(602)=15.50
P(603)=15.50
P(604)=15.50

P(605)=15.50
P(606)=15.50
P(607)=15.50
P(608)=15.50
P(609)=15.50
P(610)=15.50
P(611)=15.50
P(612)=15.50
P(613)=15.50
P(614)=15.50
P(615)=15.50
P(616)=15.50
P(617)=15.50
P(618)=-10.33
P(619)=-10.29
P(620)=-10.18
P(621)= -9.71
P(622)= -8.95
P(623)= -7.92
P(624)= -6.64
P(625)= -3.53
P(626)=000.00
P(627)= 3.53
P(628)= 6.64
P(629)= 8.95
P(630)= 9.71
P(631)= 10.18
P(632)= 10.33
P(633)= 10.18
P(634)= 9.71
P(635)= 8.95
P(636)= 6.64
P(637)= 3.53
P(638)=000.00
P(639)= -3.53
P(640)= -6.64
P(641)= -7.92
P(642)= -8.95
P(643)= -9.71
P(644)=-10.18
P(645)=-10.29
P(646)=-20.67
P(647)=-20.59
P(648)=-20.35
P(649)=-19.42
P(650)=-17.90
P(651)=-15.83
P(652)=-13.29
P(653)= -7.07
P(654)=000.00
P(655)= 7.07
P(656)= 13.29
P(657)= 17.90
P(658)= 19.42
P(659)= 20.35
P(660)= 20.67
P(661)= 20.35
P(662)= 19.42
P(663)= 17.90
P(664)= 13.29
P(665)= 7.07
P(666)=000.00
P(667)= -7.07
P(668)=-13.29
P(669)=-15.83
P(670)=-17.90
P(671)=-19.42
P(672)=-20.35
P(673)=-20.59
P(674)=-31.00
P(675)=-30.88
P(676)=-30.53
P(677)=-29.13
P(678)=-26.85
P(679)=-23.75
P(680)=-19.93
P(681)=-10.60
P(682)=000.00
P(683)= 10.60
P(684)= 19.93
P(685)= 26.85
P(686)= 29.13
P(687)= 30.53
P(688)= 31.00
P(689)= 30.53
P(690)= 29.13
P(691)= 26.85
P(692)= 19.93
P(693)= 10.60
P(694)=000.00
P(695)=-10.60
P(696)=-19.93
P(697)=-23.75
P(698)=-26.85
P(699)=-29.13
P(700)=-30.53
P(701)=-30.88

```
P( 702)=-41.34
P( 703)=-41.18
P( 704)=-40.71
P( 705)=-38.84
P( 706)=-35.80
P( 707)=-31.67
P( 708)=-26.57
P( 709)=-14.14
P( 710)=000.00
P( 711)= 14.14
P( 712)= 26.57
P( 713)= 35.80
P( 714)= 38.84
P( 715)= 40.71
P( 716)= 41.34
P( 717)= 40.71
P( 718)= 38.84
P( 719)= 35.80
P( 720)= 26.57
P( 721)= 14.14
P( 722)=000.00
P( 723)=-14.14
P( 724)=-26.57
P( 725)=-31.67
P( 726)=-35.80
P( 727)=-38.84
P( 728)=-40.71
P( 729)=-41.18
P( 730)=-51.67
P( 731)=-51.47
P( 732)=-50.89
P( 733)=-48.55
P( 734)=-44.75
P( 735)=-39.58
P( 736)=-33.21
P( 737)=-17.67
P( 738)=000.00
P( 739)= 17.67
P( 740)= 33.21
P( 741)= 44.75
P( 742)= 48.55
P( 743)= 50.89
P( 744)= 51.67
P( 745)= 50.89
P( 746)= 48.55
P( 747)= 44.75
P( 748)= 33.21
P( 749)= 17.67
P( 750)=000.00
P( 751)=-17.67
P( 752)=-33.21
P( 753)=-39.58
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      N(1303)=7226
      N(1304)=7227
      N(1305)=7228
      N(1306)=7229
      N(1307)=7230
      REWIND 13
      DO 1 J=29,1307
      WRITE(13) N(J),P(J)
    1 CONTINUE
      END FILE 13
      REWIND 13
      STOP
      END
```

TABLE B-I. - OUTPUT SYMBOLS

Variables represented	Program output symbols	Variables represented	Program output symbols
$\ddot{\overline{\overline{\overline{X}}}}_1$	X1DD	$\dot{\Omega}_{z,1}$	OZ1D
$\ddot{\overline{\overline{\overline{Y}}}}_1$	Y1DD	$\dot{\Omega}_{x,2}$	OX2D
$\ddot{\overline{\overline{\overline{Z}}}}_1$	Z1DD	$\dot{\Omega}_{y,2}$	OY2D
$\ddot{\overline{\overline{\overline{X}}}}_2$	X2DD	$\dot{\Omega}_{z,2}$	OZ2D
$\ddot{\overline{\overline{\overline{Y}}}}_2$	Y2DD	$\Omega_{x,1}$	OX1
$\ddot{\overline{\overline{\overline{Z}}}}_2$	Z2DD	$\Omega_{y,1}$	OY1
$\dot{\overline{\overline{\overline{X}}}}_1$	X1D	$\Omega_{z,1}$	OZ1
$\dot{\overline{\overline{\overline{Y}}}}_1$	Y1D	$\Omega_{x,2}$	OX2
$\dot{\overline{\overline{\overline{Z}}}}_1$	Z1D	$\Omega_{y,2}$	OY2
$\dot{\overline{\overline{\overline{X}}}}_2$	X2D	$\Omega_{z,2}$	OZ2
$\dot{\overline{\overline{\overline{Y}}}}_2$	Y2D	$F_{S, MAX}$	FSMX
$\dot{\overline{\overline{\overline{Z}}}}_2$	Z2D	$N_{S, MAX}$	S NO
$\overline{\overline{\overline{X}}}_1$	X1	$F_{H, MAX}$	FHMX
$\overline{\overline{\overline{Y}}}_1$	Y1	$N_{H, MAX}$	H NO
$\overline{\overline{\overline{Z}}}_1$	Z1	$S_{S, MAX}$	SSMX
$\overline{\overline{\overline{X}}}_2$	X2	$N_{S, S, MAX}$	S NO
$\overline{\overline{\overline{Y}}}_2$	Y2	θ_1	TH1
$\overline{\overline{\overline{Z}}}_2$	Z2	ϕ_1	PH1
$\dot{\Omega}_{x,1}$	OX1D	ψ_1	PS1
$\dot{\Omega}_{y,1}$	OY1D	θ_2	TH2
ϕ_2	PH2	$GS_{i,1}$	GXGR

TABLE B-I. - OUTPUT SYMBOLS - Concluded

Variables represented	Program output symbols	Variables represented	Program output symbols
ψ_2	PS2	$GS_{j,1}$	GYGR
t	TIME	$GS_{k,1}$	GZGR
$\bar{\theta}$	THBR	YHSM	YHSM
$\bar{\psi}$	PSBR	NPHS	NPHS
$\bar{\phi}$	PHBR	YR1M	YR1M
$S_{H,MAX}$	SHMX	NPR1	NPR1
$N_{S,H,MAX}$	H NO	YR2M	YR2M
X_1	XBR1	NPR2	NPR2
Y_1	YBR1	YR3M	YR3M
Z_1	ZBR1	NPR3	NPR3
SE3P	SE3P	$\bar{\bar{Z}}_1$	ZBAR2 to $c.g._1$
SE3M	SE3M	$\bar{\bar{Y}}_1$	YBAR2 to $c.g._1$
β	SANG	$\bar{\bar{X}}_1$	XBAR2 to $c.g._1$
$FS_{i,1}$	FXGR	$\dot{\bar{\bar{X}}}_1$	INERTIALX1D
$FS_{j,1}$	FYGR	$\dot{\bar{\bar{Y}}}_1$	INERTIALY1D
$FS_{k,1}$	FZGR	$\dot{\bar{\bar{Z}}}_1$	INERTIALZ1D

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN

(a) 1 39 6 6 170 0 1 28 -1		266	.60850000+02
3	.60276000+05	267	.60850000+02
4	.68700000+05	282	-.11850000+02
5	.54096000+05	283	.14650000+02
6	.29066000+02	284	-.10850000+02
10	.10000000+01	285	.13650000+02
14	.10000000+01	286	-.10850000+02
18	.10000000+01	287	.13650000+02
19	.45400000+03	302	-.62580000+01
20	.13790000+04	303	-.62580000+01
21	.11340000+04	304	.33530000+01
22	.25690000+01	305	.33530000+01
26	.10000000+01	306	-.13007000+02
30	.10000000+01	307	-.13007000+02
34	.10000000+01	322	.28100000+02
140	-.14000000+01	323	.28100000+02
141	.53000000+01	324	-.24095000+02
142	.18500000+02	325	-.24095000+02
143	.97899999+00	326	.60620000+01
144	-.36195000+02	327	.60620000+01
145	.55369999+01	421	.42000000+02
146	-.97899999+00	424	-.42000000+02
147	-.36195000+02	427	.43400000+02
148	.55369999+01	428	-.11288000+02
149	.18940000+01	429	-.91199999+01
150	-.33961000+02	430	-.40600000+02
151	.88140000+00	431	-.11288000+02
152	-.18940000+01	432	-.91199999+01
153	-.33961000+02	582	.36629000+02
154	.88140000+00	583	.36629000+02
155	.37900000+00	584	.34025000+02
156	.14493000+02	585	.34025000+02
157	-.36289000+02	586	.39079000+02
158	-.37900000+00	587	.39079000+02
159	.14493000+02	965	.00000000
160	-.36289000+02	966	-.37200000+02
222	-.14229000+02	967	.66000000+01
223	.14229000+02	968	.17640000+03
224	-.14143000+02	2743	.66250000+04
225	.14143000+02	2744	.16000000+05
226	-.12632000+02	2745	.41406000+00
227	.12632000+02	2746	.16000000+05
242	.35237000+02	2184	.17000000-01
243	.35237000+02	2185	.17000000-01
244	.42613000+02	2186	.17000000-01
245	.42613000+02	2187	.17000000-01
246	-.22200000+02	2188	.17000000-01
247	-.22200000+02	2189	.17000000-01
262	.41069000+02	2204	.30400000+04
263	.41069000+02	2205	.30400000+04
264	-.64760000+01	2206	.39240000+04
265	-.64760000+01	2207	.39240000+04

[a]Card data; other entries are tape data.

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

2208	.32740000+04	2389	.73000000+05
2209	.32740000+04	2404	.73000000+05
2224	.17000000-01	2405	.73000000+05
2225	.17000000-01	2406	.73000000+05
2226	.17000000-01	2407	.73000000+05
2227	.17000000-01	2408	.73000000+05
2228	.17000000-01	2409	.73000000+05
2229	.17000000-01	2664	.00000000
2244	.30400000+04	2665	.00000000
2245	.30400000+04	2666	.00000000
2246	.39240000+04	2667	.00000000
2247	.39240000+04	2668	.00000000
2248	.44590000+04	2669	.00000000
2249	.44590000+04	2684	.00000000
2264	.10000000+07	2685	.00000000
2265	.10000000+07	2686	.00000000
2266	.10000000+07	2687	.00000000
2267	.10000000+07	2688	.00000000
2268	.10000000+07	2689	.00000000
2269	.10000000+07	2704	.00000000
2284	.16200000+02	2705	.00000000
2285	.16200000+02	2706	.00000000
2286	.16200000+02	2707	.00000000
2287	.16200000+02	2708	.00000000
2288	.18200000+02	2709	.00000000
2289	.18200000+02	2724	.00000000
2304	.16000000+02	2725	.00000000
2305	.16000000+02	2726	.00000000
2306	.16000000+02	2727	.00000000
2307	.16000000+02	2728	.00000000
2308	.18000000+02	2729	.00000000
2309	.18000000+02	3960	.58400000-01
2324	.10000000+07	3961	.60000000+02
2325	.10000000+07	3962	.37000000+00
2326	.10000000+07	3963	.20000000+05
2327	.10000000+07	3964	.17800000+02
2328	.10000000+07	3965	.36000000+04
2329	.10000000+07	3966	.25000000+00
2344	.12000000+01	3967	.57585000+00
2345	.12000000+01	983	.00000000
2346	.12000000+01	984	.90000000+00
2347	.12000000+01	985	.17900000+01
2348	.52000000+01	986	.35300000+01
2349	.52000000+01	987	.51700000+01
2364	.10000000+01	988	.66400000+01
2365	.10000000+01	989	.79200000+01
2366	.10000000+01	990	.97099999+01
2367	.10000000+01	991	.10330000+02
2368	.50000000+01	992	.97099999+01
2369	.50000000+01	993	.79200000+01
2384	.73000000+05	994	.51700000+01
2385	.73000000+05	995	.35300000+01
2386	.73000000+05	996	.17900000+01
2387	.73000000+05	997	.00000000
2388	.73000000+05	998	-.17900000+01

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

999	-.35300000+01	1053	.00000000
1000	-.51700000+01	1054	-.53800000+01
1001	-.79200000+01	1055	-.10600000+02
1002	-.97099999+01	1056	-.15500000+02
1003	-.10330000+02	1057	-.23750000+02
1004	-.97099999+01	1058	-.29130000+02
1005	-.79200000+01	1059	-.31000000+02
1006	-.66400000+01	1060	-.29130000+02
1007	-.51700000+01	1061	-.23750000+02
1008	-.35300000+01	1062	-.19930000+02
1009	-.17900000+01	1063	-.15500000+02
1010	-.90000000+00	1064	-.10600000+02
1011	.00000000	1065	-.53800000+01
1012	.18000000+01	1066	-.27000000+01
1013	.35900000+01	1067	.00000000
1014	.70700000+01	1068	.36000000+01
1015	.10330000+02	1069	.71799999+01
1016	.13290000+02	1070	.14140000+02
1017	.15830000+02	1071	.20670000+02
1018	.19420000+02	1072	.26570000+02
1019	.20670000+02	1073	.31670000+02
1020	.19420000+02	1074	.38840000+02
1021	.15830000+02	1075	.41340000+02
1022	.10330000+02	1076	.38840000+02
1023	.70700000+01	1077	.31670000+02
1024	.35900000+01	1078	.20670000+02
1025	.00000000	1079	.14140000+02
1026	-.35900000+01	1080	.71799999+01
1027	-.70700000+01	1081	.00000000
1028	-.10330000+02	1082	-.71799999+01
1029	-.15830000+02	1083	-.14140000+02
1030	-.19420000+02	1084	-.20670000+02
1031	-.20670000+02	1085	-.31670000+02
1032	-.19420000+02	1086	-.38840000+02
1033	-.15830000+02	1087	-.41340000+02
1034	-.13290000+02	1088	-.38840000+02
1035	-.10330000+02	1089	-.31670000+02
1036	-.70700000+01	1090	-.26570000+02
1037	-.35900000+01	1091	-.20670000+02
1038	-.18000000+01	1092	-.14140000+02
1039	.00000000	1093	-.71799999+01
1040	.27000000+01	1094	-.36000000+01
1041	.53800000+01	1095	.00000000
1042	.10600000+02	1096	.45000000+01
1043	.15500000+02	1097	.89699999+01
1044	.19930000+02	1098	.17670000+02
1045	.23750000+02	1099	.25840000+02
1046	.29130000+02	1100	.33210000+02
1047	.31000000+02	1101	.39580000+02
1048	.29130000+02	1102	.48550000+02
1049	.23750000+02	1103	.51670000+02
1050	.15500000+02	1104	.48550000+02
1051	.10600000+02	1105	.39580000+02
1052	.53800000+01	1106	.25840000+02

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

1107	.17670000+02
1108	.89699999+01
1109	.00000000
1110	-.89699999+01
1111	-.17670000+02
1112	-.25840000+02
1113	-.39580000+02
1114	-.48550000+02
1115	-.51670000+02
1116	-.48550000+02
1117	-.39580000+02
1118	-.33210000+02
1119	-.25840000+02
1120	-.17670000+02
1121	-.89699999+01
1122	-.45000000+01
1123	.00000000
1124	.57600000+01
1125	.11490000+02
1126	.22500000+02
1127	.33070000+02
1128	.42510000+02
1129	.50670000+02
1130	.62150000+02
1131	.66139999+02
1132	.62150000+02
1133	.50670000+02
1134	.33070000+02
1135	.22500000+02
1136	.11490000+02
1137	.00000000
1138	-.11490000+02
1139	-.22500000+02
1140	-.33070000+02
1141	-.50670000+02
1142	-.62150000+02
1143	-.66139999+02
1144	-.62150000+02
1145	-.50670000+02
1146	-.42510000+02
1147	-.33070000+02
1148	-.22500000+02
1149	-.11490000+02
1150	-.57600000+01
1151	.00000000
1152	.63099999+01
1153	.12560000+02
1154	.24740000+02
1155	.36170000+02
1156	.46500000+02
1157	.55410000+02
1158	.67980000+02
1159	.72339999+02
1160	.67980000+02
1161	.55410000+02
1162	.36170000+02
1163	.24740000+02
1164	.12560000+02
1165	.00000000
1166	-.12560000+02
1167	-.24740000+02
1168	-.36170000+02
1169	-.55410000+02
1170	-.67980000+02
1171	-.72339999+02
1172	-.67980000+02
1173	-.55410000+02
1174	-.46500000+02
1175	-.36170000+02
1176	-.24740000+02
1177	-.12560000+02
1178	-.63099999+01
1183	.30300000+00
1184	.30300000+00
1185	.30300000+00
1186	.30300000+00
1187	.30300000+00
1188	.30300000+00
1189	.30300000+00
1190	.30300000+00
1191	.30300000+00
1192	.30300000+00
1193	.30300000+00
1194	.30300000+00
1195	.30300000+00
1196	.30300000+00
1197	.30300000+00
1198	.30300000+00
1199	.30300000+00
1200	.30300000+00
1201	.30300000+00
1202	.30300000+00
1203	.30300000+00
1204	.30300000+00
1205	.30300000+00
1206	.30300000+00
1207	.30300000+00
1208	.30300000+00
1209	.30300000+00
1210	.30300000+00
1211	.12140000+01
1212	.12140000+01
1213	.12140000+01
1214	.12140000+01
1215	.12140000+01
1216	.12140000+01
1217	.12140000+01
1218	.12140000+01
1219	.12140000+01
1220	.12140000+01

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

1221	.12140000+01
1222	.12140000+01
1223	.12140000+01
1224	.12140000+01
1225	.12140000+01
1226	.12140000+01
1227	.12140000+01
1228	.12140000+01
1229	.12140000+01
1230	.12140000+01
1231	.12140000+01
1232	.12140000+01
1233	.12140000+01
1234	.12140000+01
1235	.12140000+01
1236	.12140000+01
1237	.12140000+01
1238	.12140000+01
1239	.27430000+01
1240	.27430000+01
1241	.27430000+01
1242	.27430000+01
1243	.27430000+01
1244	.27430000+01
1245	.27430000+01
1246	.27430000+01
1247	.27430000+01
1248	.27430000+01
1249	.27430000+01
1250	.27430000+01
1251	.27430000+01
1252	.27430000+01
1253	.27430000+01
1254	.27430000+01
1255	.27430000+01
1256	.27430000+01
1257	.27430000+01
1258	.27430000+01
1259	.27430000+01
1260	.27430000+01
1261	.27430000+01
1262	.27430000+01
1263	.27430000+01
1264	.27430000+01
1265	.27430000+01
1266	.27430000+01
1267	.49060000+01
1268	.49060000+01
1269	.49060000+01
1270	.49060000+01
1271	.49060000+01
1272	.49060000+01
1273	.49060000+01
1274	.49060000+01
1275	.49060000+01
1276	.49060000+01
1277	.49060000+01
1278	.49060000+01
1279	.49060000+01
1280	.49060000+01
1281	.49060000+01
1282	.49060000+01
1283	.49060000+01
1284	.49060000+01
1285	.49060000+01
1286	.49060000+01
1287	.49060000+01
1288	.49060000+01
1289	.49060000+01
1290	.49060000+01
1291	.49060000+01
1292	.49060000+01
1293	.49060000+01
1294	.49060000+01
1295	.77280000+01
1296	.77280000+01
1297	.77280000+01
1298	.77280000+01
1299	.77280000+01
1300	.77280000+01
1301	.77280000+01
1302	.77280000+01
1303	.77280000+01
1304	.77280000+01
1305	.77280000+01
1306	.77280000+01
1307	.77280000+01
1308	.77280000+01
1309	.77280000+01
1310	.77280000+01
1311	.77280000+01
1312	.77280000+01
1313	.77280000+01
1314	.77280000+01
1315	.77280000+01
1316	.77280000+01
1317	.77280000+01
1318	.77280000+01
1319	.77280000+01
1320	.77280000+01
1321	.77280000+01
1322	.77280000+01
1323	.12850000+02
1324	.12850000+02
1325	.12850000+02
1326	.12850000+02
1327	.12850000+02
1328	.12850000+02

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

1329	.12850000+02
1330	.12850000+02
1331	.12850000+02
1332	.12850000+02
1333	.12850000+02
1334	.12850000+02
1335	.12850000+02
1336	.12850000+02
1337	.12850000+02
1338	.12850000+02
1339	.12850000+02
1340	.12850000+02
1341	.12850000+02
1342	.12850000+02
1343	.12850000+02
1344	.12850000+02
1345	.12850000+02
1346	.12850000+02
1347	.12850000+02
1348	.12850000+02
1349	.12850000+02
1350	.12850000+02
1351	.15500000+02
1352	.15500000+02
1353	.15500000+02
1354	.15500000+02
1355	.15500000+02
1356	.15500000+02
1357	.15500000+02
1358	.15500000+02
1359	.15500000+02
1360	.15500000+02
1361	.15500000+02
1362	.15500000+02
1363	.15500000+02
1364	.15500000+02
1365	.15500000+02
1366	.15500000+02
1367	.15500000+02
1368	.15500000+02
1369	.15500000+02
1370	.15500000+02
1371	.15500000+02
1372	.15500000+02
1373	.15500000+02
1374	.15500000+02
1375	.15500000+02
1376	.15500000+02
1377	.15500000+02
1378	.15500000+02
1383	-.10330000+02
1384	-.10290000+02
1385	-.10180000+02
1386	-.97099999+01
1387	-.89499999+01
1388	-.79200000+01
1389	-.66400000+01
1390	-.35300000+01
1391	.00000000
1392	.35300000+01
1393	.66400000+01
1394	.89499999+01
1395	.97099999+01
1396	.10180000+02
1397	.10330000+02
1398	.10180000+02
1399	.97099999+01
1400	.89499999+01
1401	.66400000+01
1402	.35300000+01
1403	.00000000
1404	-.35300000+01
1405	-.66400000+01
1406	-.79200000+01
1407	-.89499999+01
1408	-.97099999+01
1409	-.10180000+02
1410	-.10290000+02
1411	-.20670000+02
1412	-.20590000+02
1413	-.20350000+02
1414	-.19420000+02
1415	-.17900000+02
1416	-.15830000+02
1417	-.13290000+02
1418	-.70700000+01
1419	.00000000
1420	.70700000+01
1421	.13290000+02
1422	.17900000+02
1423	.19420000+02
1424	.20350000+02
1425	.20670000+02
1426	.20350000+02
1427	.19420000+02
1428	.17900000+02
1429	.13290000+02
1430	.70700000+01
1431	.00000000
1432	-.70700000+01
1433	-.13290000+02
1434	-.15830000+02
1435	-.17900000+02
1436	-.19420000+02
1437	-.20350000+02
1438	-.20590000+02
1439	-.31000000+02
1440	-.30880000+02

1441	-.30530000+02
1442	-.29130000+02
1443	-.26850000+02
1444	-.23750000+02
1445	-.19930000+02
1446	-.10600000+02
1447	.00000000
1448	.10600000+02
1449	.19930000+02
1450	.26850000+02
1451	.29130000+02
1452	.30530000+02
1453	.31000000+02
1454	.30530000+02
1455	.29130000+02
1456	.26850000+02
1457	.19930000+02
1458	.10600000+02
1459	.00000000
1460	-.10600000+02
1461	-.19930000+02
1462	-.23750000+02
1463	-.26850000+02
1464	-.29130000+02
1465	-.30530000+02
1466	-.30880000+02
1467	-.41340000+02
1468	-.41180000+02
1469	-.40710000+02
1470	-.38840000+02
1471	-.35800000+02
1472	-.31670000+02
1473	-.26570000+02
1474	-.14140000+02
1475	.00000000
1476	.14140000+02
1477	.26570000+02
1478	.35800000+02
1479	.38840000+02
1480	.40710000+02
1481	.41340000+02
1482	.40710000+02
1483	.38840000+02
1484	.35800000+02
1485	.26570000+02
1486	.14140000+02
1487	.00000000
1488	-.14140000+02
1489	-.26570000+02
1490	-.31670000+02
1491	-.35800000+02
1492	-.38840000+02
1493	-.40710000+02
1494	-.41180000+02
1495	-.51670000+02
1496	-.51470000+02
1497	-.50890000+02
1498	-.48550000+02
1499	-.44750000+02
1500	-.39580000+02
1501	-.33210000+02
1502	-.17670000+02
1503	.00000000
1504	.17670000+02
1505	.33210000+02
1506	.44750000+02
1507	.48550000+02
1508	.50890000+02
1509	.51670000+02
1510	.50890000+02
1511	.48550000+02
1512	.44750000+02
1513	.33210000+02
1514	.17670000+02
1515	.00000000
1516	-.17670000+02
1517	-.33210000+02
1518	-.39580000+02
1519	-.44750000+02
1520	-.48550000+02
1521	-.50890000+02
1522	-.51470000+02
1523	-.66139999+02
1524	-.65889999+02
1525	-.65129999+02
1526	-.62150000+02
1527	-.57280000+02
1528	-.50670000+02
1529	-.42510000+02
1530	-.22500000+02
1531	.00000000
1532	.22500000+02
1533	.42510000+02
1534	.57280000+02
1535	.62150000+02
1536	.65129999+02
1537	.66139999+02
1538	.65129999+02
1539	.62150000+02
1540	.57280000+02
1541	.42510000+02
1542	.22500000+02
1543	.00000000
1544	-.22500000+02
1545	-.42510000+02
1546	-.50670000+02

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

1547	-.57280000+02	5202	.30000000-01
1548	-.62150000+02	5203	.30000000-01
1549	-.65129999+02	5204	.30000000-01
1550	-.65889999+02	5205	.30000000-01
1551	-.72339999+02	5206	.30000000-01
1552	-.72059999+02	5207	.30000000-01
1553	-.71240000+02	5208	.50000000-01
1554	-.67980000+02	5209	.50000000-01
1555	-.62650000+02	5210	.50000000-01
1556	-.55410000+02	5211	.50000000-01
1557	-.46500000+02	5212	.50000000-01
1558	-.24740000+02	5213	.50000000-01
1559	.00000000	5214	.50000000-01
1560	.24740000+02	5215	.30000000-01
1561	.46500000+02	5216	.30000000-01
1562	.62650000+02	5217	.30000000-01
1563	.67980000+02	5218	.20000000-01
1564	.71240000+02	5219	.20000000-01
1565	.72339999+02	5220	.20000000-01
1566	.71240000+02	5221	.20000000-01
1567	.67980000+02	5222	.20000000-01
1568	.62650000+02	5223	.20000000-01
1569	.46500000+02	5224	.20000000-01
1570	.24740000+02	5225	.20000000-01
1571	.00000000	5226	.20000000-01
1572	-.24740000+02	5227	.30000000-01
1573	-.46500000+02	5228	.30000000-01
1574	-.55410000+02	5229	.30000000-01
1575	-.62650000+02	5230	.50000000-01
1576	-.67980000+02	5231	.50000000-01
1577	-.71240000+02	5232	.50000000-01
1578	-.72059999+02	5233	.50000000-01
5180	.30000000-01	5234	.50000000-01
5181	.30000000-01	5235	.50000000-01
5182	.30000000-01	5236	.50000000-01
5183	.30000000-01	5237	.50000000-01
5184	.30000000-01	5238	.50000000-01
5185	.30000000-01	5239	.50000000-01
5186	.30000000-01	5240	.50000000-01
5187	.30000000-01	5241	.50000000-01
5188	.30000000-01	5242	.50000000-01
5189	.30000000-01	5243	.30000000-01
5190	.30000000-01	5244	.30000000-01
5191	.30000000-01	5245	.20000000-01
5192	.20000000-01	5246	.20000000-01
5193	.20000000-01	5247	.20000000-01
5194	.20000000-01	5248	.20000000-01
5195	.20000000-01	5249	.20000000-01
5196	.20000000-01	5250	.12000000-01
5197	.30000000-01	5251	.20000000-01
5198	.30000000-01	5252	.20000000-01
5199	.30000000-01	5253	.20000000-01
5200	.30000000-01	5254	.20000000-01
5201	.30000000-01	5255	.20000000-01

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

5256	.30000000-01
5257	.30000000-01
5258	.50000000-01
5259	.50000000-01
5260	.50000000-01
5261	.50000000-01
5262	.50000000-01
5263	.50000000-01
5264	.50000000-01
5265	.50000000-01
5266	.50000000-01
5267	.50000000-01
5268	.50000000-01
5269	.50000000-01
5270	.50000000-01
5271	.30000000-01
5272	.20000000-01
5273	.20000000-01
5274	.12000000-01
5275	.12000000-01
5276	.12000000-01
5277	.12000000-01
5278	.12000000-01
5279	.12000000-01
5280	.12000000-01
5281	.12000000-01
5282	.12000000-01
5283	.20000000-01
5284	.20000000-01
5285	.30000000-01
5286	.50000000-01
5287	.50000000-01
5288	.50000000-01
5289	.50000000-01
5290	.50000000-01
5291	.50000000-01
5292	.50000000-01
5293	.50000000-01
5294	.50000000-01
5295	.50000000-01
5296	.50000000-01
5297	.50000000-01
5298	.50000000-01
5299	.30000000-01
5300	.20000000-01
5301	.20000000-01
5302	.12000000-01
5303	.12000000-01
5304	.12000000-01
5305	.12000000-01
5306	.12000000-01
5307	.12000000-01
5308	.12000000-01
5309	.12000000-01
5310	.12000000-01
5311	.20000000-01
5312	.20000000-01
5313	.30000000-01
5314	.50000000-01
5315	.50000000-01
5316	.50000000-01
5317	.50000000-01
5318	.50000000-01
5319	.50000000-01
5320	.12000000-01
5321	.12000000-01
5322	.12000000-01
5323	.12000000-01
5324	.12000000-01
5325	.12000000-01
5326	.12000000-01
5327	.12000000-01
5328	.12000000-01
5329	.12000000-01
5330	.12000000-01
5331	.12000000-01
5332	.12000000-01
5333	.12000000-01
5334	.12000000-01
5335	.12000000-01
5336	.12000000-01
5337	.12000000-01
5338	.12000000-01
5339	.12000000-01
5340	.12000000-01
5341	.12000000-01
5342	.12000000-01
5343	.12000000-01
5344	.12000000-01
5345	.12000000-01
5346	.12000000-01
5347	.12000000-01
5348	.12000000-01
5349	.12000000-01
5350	.12000000-01
5351	.12000000-01
5352	.12000000-01
5353	.12000000-01
5354	.12000000-01
5355	.12000000-01
5356	.12000000-01
5357	.12000000-01
5358	.12000000-01
5359	.12000000-01
5360	.12000000-01
5361	.12000000-01
5362	.12000000-01
5363	.12000000-01

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

5364	.12000000-01	6510	.13000000+03
5365	.12000000-01	6511	.15000000+03
5366	.12000000-01	6512	.16000000+03
5367	.12000000-01	6513	.17000000+03
5368	.12000000-01	6514	.18000000+03
5369	.12000000-01	6515	.19000000+03
5370	.12000000-01	6516	.20000000+03
5371	.12000000-01	6517	.21000000+03
5372	.12000000-01	6518	.23000000+03
5373	.12000000-01	6519	.25000000+03
5374	.12000000-01	6520	.27000000+03
5375	.12000000-01	6521	.29000000+03
5376	.50000000-01	6522	.31000000+03
5377	.50000000-01	6523	.32000000+03
5378	.50000000-01	6524	.33000000+03
5379	.50000000-01	6525	.34000000+03
5380	.50000000-01	6526	.35000000+03
5381	.50000000-01	6527	.35500000+03
5382	.50000000-01	6528	.36000000+03
5383	.30000000-01	6541	.10334140+02
5384	.20000000-01	6542	.20668280+02
5385	.12000000-01	6543	.31002420+02
5386	.12000000-01	6544	.41336560+02
5387	.12000000-01	6545	.51670700+02
5388	.12000000-01	6546	.58433000+02
5389	.12000000-01	6547	.66138499+02
5390	.12000000-01	6548	.72339000+02
5391	.12000000-01	6561	.87200000+02
5392	.12000000-01	6562	.87000000+02
5393	.12000000-01	6563	.77599999+02
5394	.12000000-01	5935	.88500000+02
5395	.12000000-01	5936	.17000000+02
5396	.20000000-01	5937	-.22400000+02
5397	.30000000-01	7009	.25000000+04
5398	.50000000-01	7010	.36000000+01
5399	.50000000-01	7011	.25000000+04
5400	.50000000-01	7012	.36000000+01
5401	.50000000-01	7013	.25000000+04
5402	.50000000-01	7014	.36000000+01
5403	.50000000-01	7015	.00000000
5939	.20000000+01	7016	.19220000+02
5943	.31818000+08	7017	.37130000+02
5944	.26100000+00	7018	.52500000+02
5940	.80000000+01	7019	.64299999+02
5941	.28000000+02	7020	.71719999+02
5942	.60000000+01	7021	.74250000+02
6501	.50000000+01	7022	.71719999+02
6502	.10000000+02	7023	.64299999+02
6503	.20000000+02	7024	.52500000+02
6504	.30000000+02	7025	.37130000+02
6505	.40000000+02	7026	.19220000+02
6506	.50000000+02	7027	.00000000
6507	.70000000+02	7028	-.19220000+02
6508	.90000000+02	7029	-.37130000+02
6509	.11000000+03	7030	-.52500000+02

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

7031	-.64299999+02
7032	-.71719999+02
7033	-.74250000+02
7034	-.71719999+02
7035	-.64299999+02
7036	-.52500000+02
7037	-.37130000+02
7038	-.19220000+02
7039	.00000000
7040	.19610000+02
7041	.37880000+02
7042	.53560000+02
7043	.65599999+02
7044	.73169999+02
7045	.75750000+02
7046	.73169999+02
7047	.65599999+02
7048	.53560000+02
7049	.37880000+02
7050	.19610000+02
7051	.00000000
7052	-.19610000+02
7053	-.37880000+02
7054	-.53560000+02
7055	-.65599999+02
7056	-.73169999+02
7057	-.75750000+02
7058	-.73169999+02
7059	-.65599999+02
7060	-.53560000+02
7061	-.37880000+02
7062	-.19610000+02
7063	.00000000
7064	.19230000+02
7065	.37150000+02
7066	.52530000+02
7067	.64339999+02
7068	.71759999+02
7069	.74290000+02
7070	.71759999+02
7071	.64339999+02
7072	.52530000+02
7073	.37150000+02
7074	.19230000+02
7075	.00000000
7076	-.19230000+02
7077	-.37150000+02
7078	-.52530000+02
7079	-.64339999+02
7080	-.71759999+02
7081	-.74290000+02
7082	-.71759999+02
7083	-.64339999+02
7084	-.52530000+02
7085	-.37150000+02
7086	-.19230000+02
7087	.16880000+02
7088	.16880000+02
7089	.16880000+02
7090	.16880000+02
7091	.16880000+02
7092	.16880000+02
7093	.16880000+02
7094	.16880000+02
7095	.16880000+02
7096	.16880000+02
7097	.16880000+02
7098	.16880000+02
7099	.16880000+02
7100	.16880000+02
7101	.16880000+02
7102	.16880000+02
7103	.16880000+02
7104	.16880000+02
7105	.16880000+02
7106	.16880000+02
7107	.16880000+02
7108	.16880000+02
7109	.16880000+02
7110	.16880000+02
7111	.21070000+02
7112	.21070000+02
7113	.21070000+02
7114	.21070000+02
7115	.21070000+02
7116	.21070000+02
7117	.21070000+02
7118	.21070000+02
7119	.21070000+02
7120	.21070000+02
7121	.21070000+02
7122	.21070000+02
7123	.21070000+02
7124	.21070000+02
7125	.21070000+02
7126	.21070000+02
7127	.21070000+02
7128	.21070000+02
7129	.21070000+02
7130	.21070000+02
7131	.21070000+02
7132	.21070000+02
7133	.21070000+02
7134	.21070000+02
7135	.25000000+02
7136	.25000000+02
7137	.25000000+02
7138	.25000000+02
7139	.25000000+02
7140	.25000000+02

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Continued

7141	.25000000+02	7193		.65599999+02
7142	.25000000+02	7194		.73169999+02
7143	.25000000+02	7195		.75750000+02
7144	.25000000+02	7196		.73169999+02
7145	.25000000+02	7197		.65599999+02
7146	.25000000+02	7198		.53560000+02
7147	.25000000+02	7199		.37880000+02
7148	.25000000+02	7200		.19610000+02
7149	.25000000+02	7201		.00000000
7150	.25000000+02	7202		-.19610000+02
7151	.25000000+02	7203		-.37880000+02
7152	.25000000+02	7204		-.53560000+02
7153	.25000000+02	7205		-.65599999+02
7154	.25000000+02	7206		-.73169999+02
7155	.25000000+02	7207		-.74290000+02
7156	.25000000+02	7208		-.71759999+02
7157	.25000000+02	7209		-.64339999+02
7158	.25000000+02	7210		-.52530000+02
7159	-.74250000+02	7211		-.37150000+02
7160	-.71719999+02	7212		-.19230000+02
7161	-.64299999+02	7213		.00000000
7162	-.52500000+02	7214		.19230000+02
7163	-.37130000+02	7215		.37150000+02
7164	-.19220000+02	7216		.52530000+02
7165	.00000000	7217		.64339999+02
7166	.19220000+02	7218		.71759999+02
7167	.37130000+02	7219		.74290000+02
7168	.52500000+02	7220		.71759999+02
7169	.64299999+02	7221		.64339999+02
7170	.71719999+02	7222		.52530000+02
7171	.74250000+02	7223		.37150000+02
7172	.71719999+02	7224		.19230000+02
7173	.64299999+02	7225		.00000000
7174	.52500000+02	7226		-.19230000+02
7175	.37130000+02	7227		-.37150000+02
7176	.19220000+02	7228		-.52530000+02
7177	.00000000	7229		-.64339999+02
7178	-.19220000+02	7230		-.71759999+02
7179	-.37130000+02	1		.10000000-02
7180	-.52500000+02	2		.10000000+00
7181	-.64299999+02	6		.26060000+02
7182	-.71719999+02	7		.20000000-02
7183	-.75750000+02	22		.26190000+01
7184	-.73169999+02	110		.43500000+02
7185	-.65599999+02	111	(a)	.32000000+02
7186	-.53560000+02	112		.00000000
7187	-.37880000+02	114		-.27500000+02
7188	-.19610000+02	115		.00000000
7189	.00000000	126		-.38609000+03
7190	.19610000+02	5995		-.14000000+01
7191	.37880000+02	5930		.53220000+01
7192	.53560000+02	5931		.75750000+02

[a]Card data; other entries are tape data.

TABLE B-II. - INPUT DATA FOR THE SAMPLE RUN - Concluded

3958	(a)	.60000000+01
3959	(a)	.20000000-01
3960	(a)	.70450000-01
3961	(a)	.10000000+03
3962	(a)	.10000000+01
3964	(a)	.15000000+00
3965	(a)	.16000000+04
3967	(a)	.55840000+00
2204	(a)	.44500000+04
2205	(a)	.36600000+04
2206	(a)	.97600000+04
2207	(a)	.90130000+04
2208	(a)	.92600000+04
2209	(a)	.51000000+04
2244	(a)	.44500000+04
2245	(a)	.36600000+04
2246	(a)	.97600000+04
2247	(a)	.90130000+04
2248	(a)	.92600000+04
2249	(a)	.51000000+04
2744	(a)	.73000000+05
2748	(a)	.73000000+05
2743	(a)	.81300000+04
2745	(a)	.11200000+00
622	(a)	.67000000+02

[a]Card data; other entries are tape data.

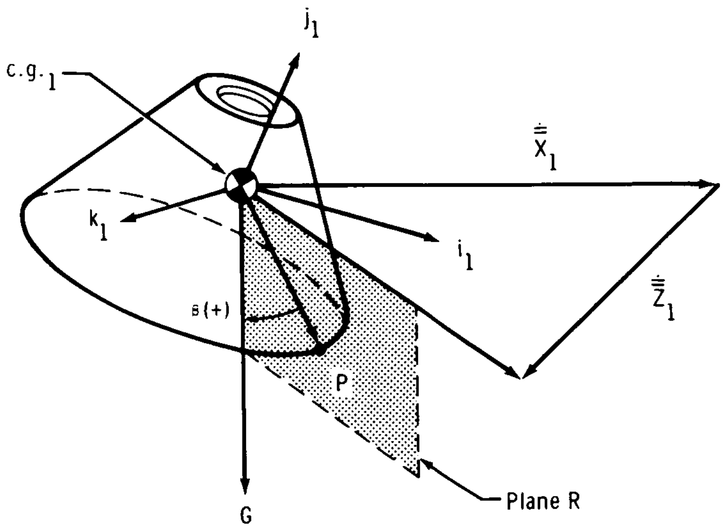


Figure B-1. - Command module stability-angle characteristics.

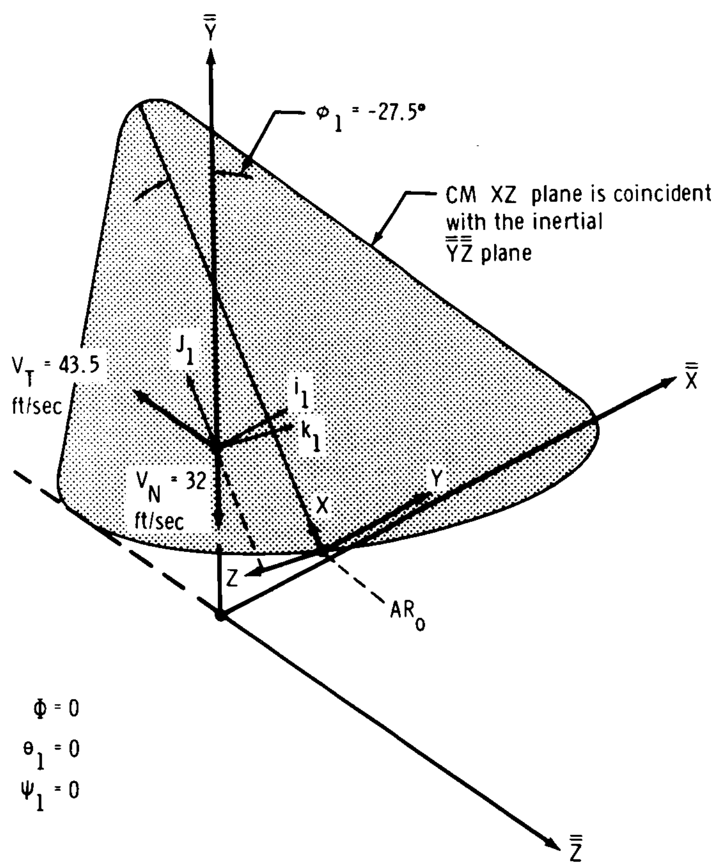


Figure B-2. - Vehicle initial conditions for the sample problem.

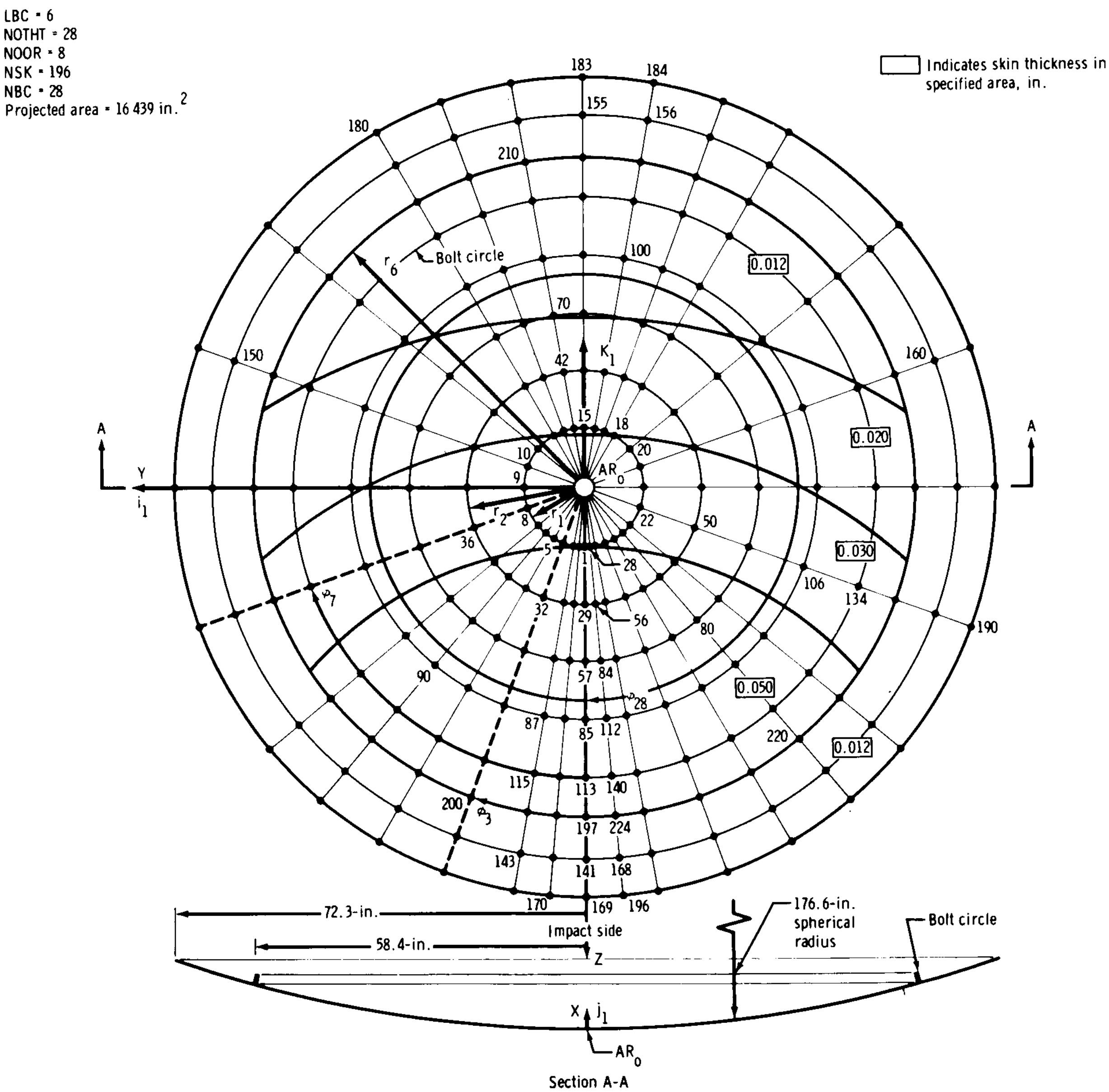
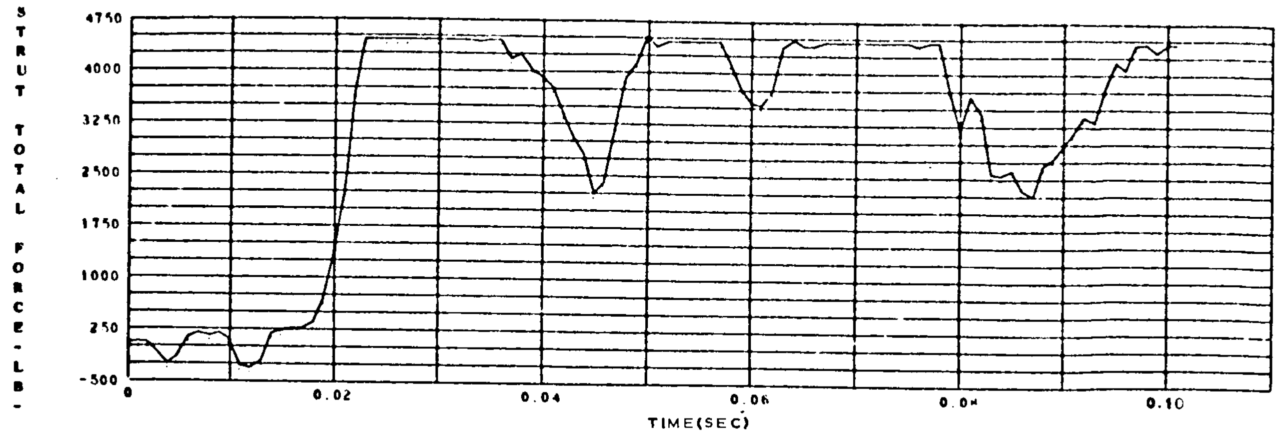


Figure B-3. - Heat-shield point pattern used for the sample run.

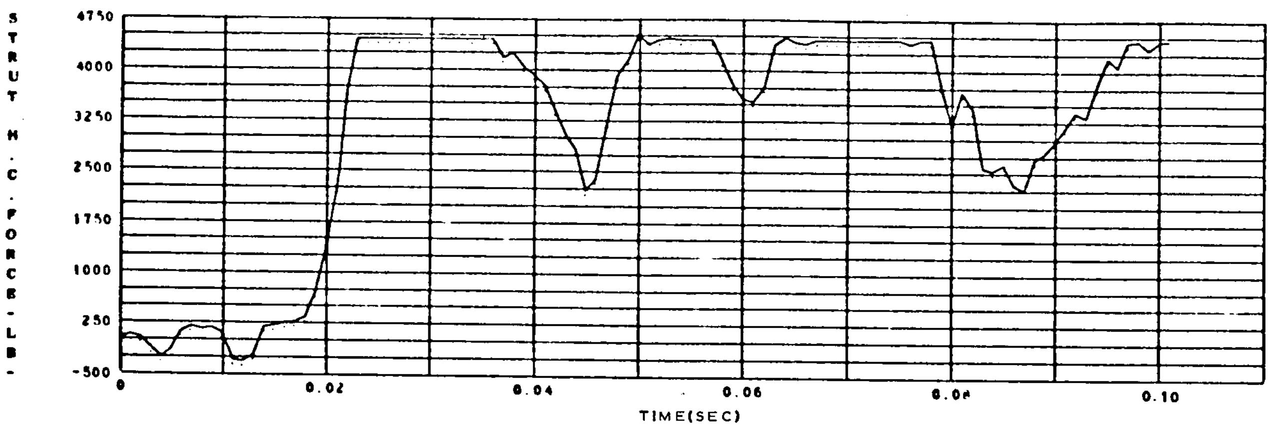
```
LOWEST NO.PT.IN CONTACT WITH SOIL IS  29  TOTAL NO.OF PTS.IN CONTACT WITH SOIL IS  25 HIGHEST NO.PT.IN CONTACT IS 136
EDGE RING FORCES I1,J1,K1=        .00000000          .00000000          .00000000
LOWEST NO.PT.IN CONTACT WITH SOIL IS  29  TOTAL NO.OF PTS.IN CONTACT WITH SOIL IS  26 HIGHEST NO.PT.IN CONTACT IS 136
EDGE RING FORCES I1,J1,K1=        .00000000          .00000000          .00000000
X1DD  -.22577743+02  Y1DD   .27722850+03  Z1DD   .54001942+03  X2DD   .22410590+03  Y2DD   .53760560+03  Z2DD  -.34923856+04
X1D   -.38850952+00  Y1D   -.36813808+02  Z1D   -.30899107+03  X2D    .20651987+01  Y2D   -.52502272+02  Z2D   -.28957717+03
X1    -.27162700-01  Y1     .38501103+02  Z1    -.38341959+02  X2    -.12384553+01  Y2     .47523258+02  Z2    -.29395980+02
OX1D   .12843334+03  OY1D   .70232784+02  OZ1D  -.37991523+02  OX2D   .90364187+04  OY2D  -.32446269+04  OZ2D   .22459012+04
OX1    .10578959+03  OY1   -.72973531+00  OZ1    .14804280+00  OX2    .10828779+03  OY2    .54735520+01  OZ2    .65786358+01
FSMX   .00000000     S NO   .00000000     FHMX   .66255078+04  H NO   .50000000+01  SSMX   .00000000     S NO   .00000000
TH1   -.54418529-01  PH1   -.20032227+02  PS1    .40098746-01  TH2    .19210429+01  PH2   -.19014754+02  PS2   -.14892234+00
TIME   .99999961-01  THBR   .19206503+01  PSBR   .49935914+00  PHBR   .10289228+01  SHMX   .72758002+01  H NO   .70000000+01
XBR1  -.11964810+01  YBR1   .54138857+01  ZBR1   .11495943+02  SE3P  -.23746490-01  SE3M   .32098770-01  SANG   .74370003+02
FXGR   .17027238+02  FYGR   .16825708+05  FZGR   .11378347+05  GXGR   .10461567+06  GYGR   .32183795+04  GZGR  -.49086694+04
YHSM   .26927531+01  NPHS           110  YR1M   .00000000     NPR1            23  YR2M   .00000000     NPR2            24
YR3M   .00000000     NPR3             0

LOWEST NO.PT.IN CONTACT WITH SOIL IS  29  TOTAL NO.OF PTS.IN CONTACT WITH SOIL IS  25 HIGHEST NO.PT.IN CONTACT IS 112
EDGE RING FORCES I1,J1,K1=        .00000000          .00000000          .00000000
X1DD  -.22403487+02  Y1DD   .23894622+03  Z1DD   .51710890+03  X2DD   .22258546+03  Y2DD   .56194699+03  Z2DD  -.33535775+04
X1D   -.39973459+00  Y1D   -.36401881+02  Z1D   -.30848804+03  X2D    .21764970+01  Y2D   -.53479712+02  Z2D   -.29274535+03
X1    -.27558606-01  Y1     .38464476+02  Z1    -.36650694+02  X2    -.12363167+01  Y2     .47470492+02  Z2    -.29687181+02
OX1D   .11091009+03  OY1D   .69248146+02  OZ1D  -.31208549+02  OX2D   .92860063+04  OY2D  -.33173770+04  OZ2D   .21077754+04
OX1    .10596822+03  OY1   -.67091605+00  OZ1    .15752585+00  OX2    .10451856+03  OY2    .28817296+01  OZ2    .62008169+01
FSMX   .00000000     S NO   .00000000     FHMX   .66526063+04  H NO   .50000000+01  SSMX   .00000000     S NO   .00000000
TH1   -.55025590-01  PH1   -.19926354+02  PS1    .40473384-01  TH2    .19271139+01  PH2   -.18906494+02  PS2   -.14377761+00
TIME   .10099996+00  THBR   .19262220+01  PSBR   .50257070+00  PHBR   .10313200+01  SHMX   .72768836+01  H NO   .70000000+01
XBR1  -.11937873+01  YBR1   .54139736+01  ZBR1   .11496915+02  SE3P  -.23746490-01  SE3M   .32098770-01  SANG   .74475879+02
FXGR   .16683258+02  FYGR   .16048165+05  FZGR   .10809373+05  GXGR   .90896579+05  GYGR   .77288222+03  GZGR  -.12828943+04
YHSM   .26938735+01  NPHS           110  YR1M   .00000000     NPR1            23  YR2M   .00000000     NPR2            24
YR3M   .00000000     NPR3             0
```

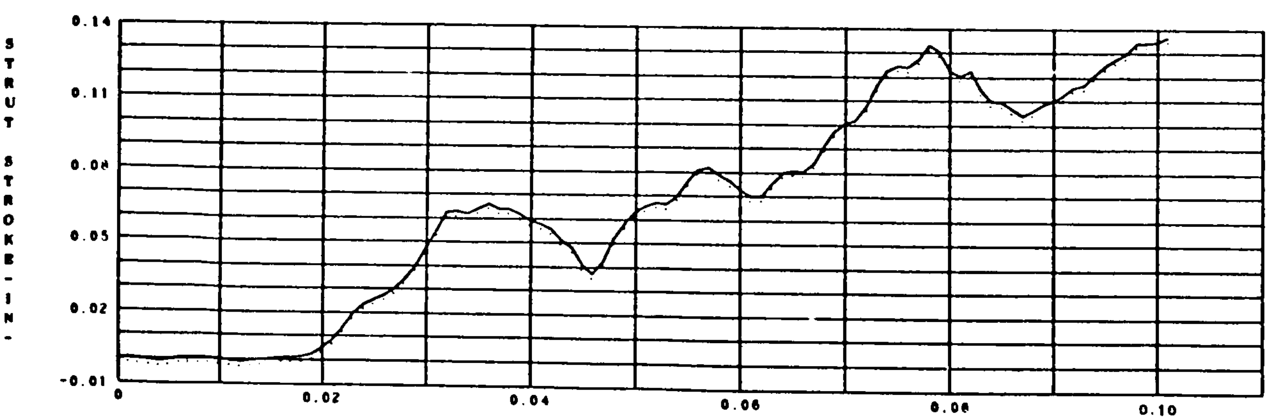
Figure B-4.- Example of the computer-program print-out for the sample run.



(a) Strut total force as a function of time.

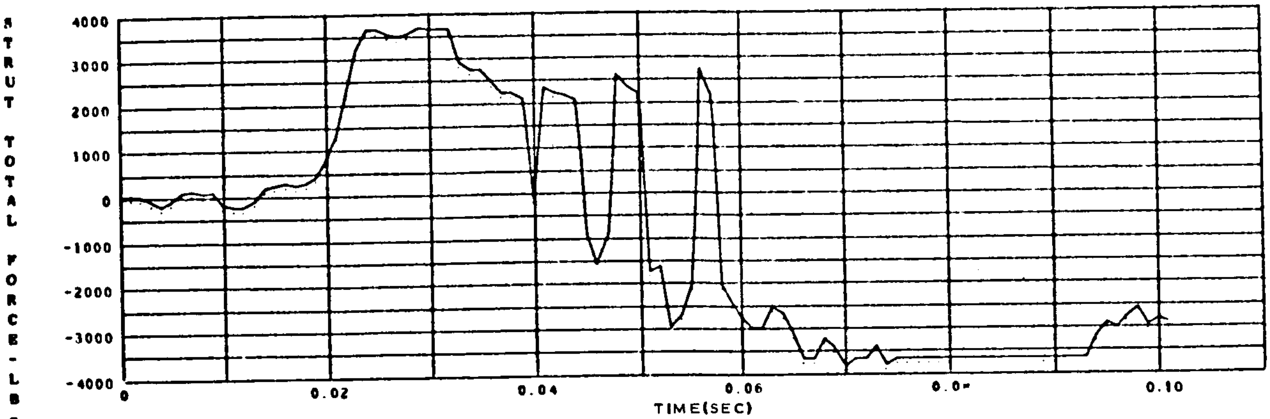


(b) Strut honeycomb force as a function of time.

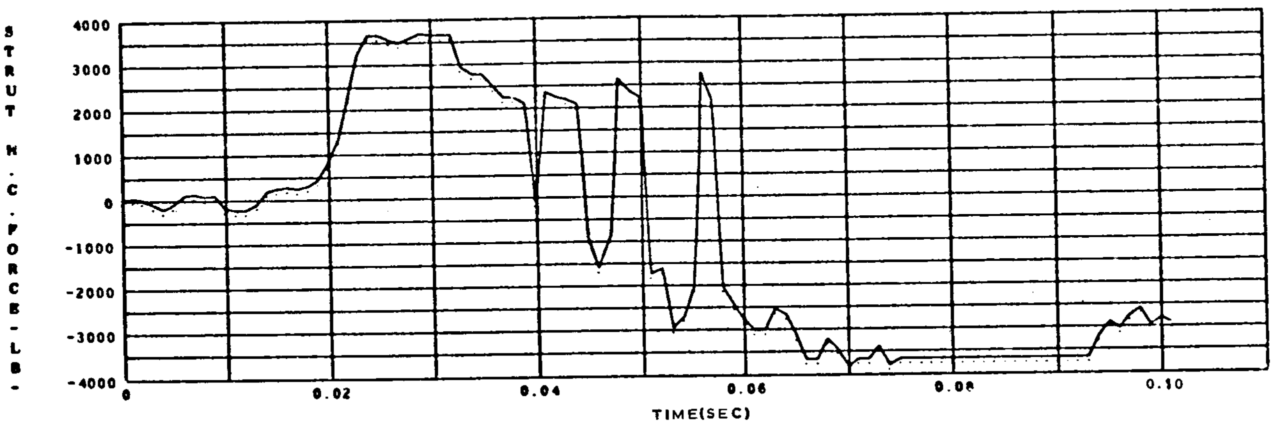


(c) Strut stroke as a function of time.

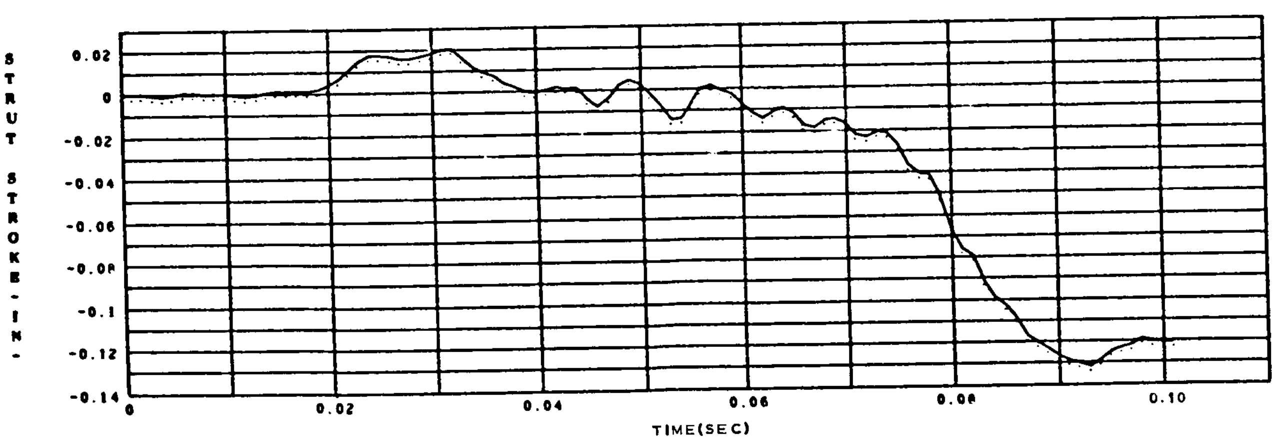
Figure B-5.- Strut 2 microfilm-recorder graphs from the sample run.



(a) Strut total force as a function of time.

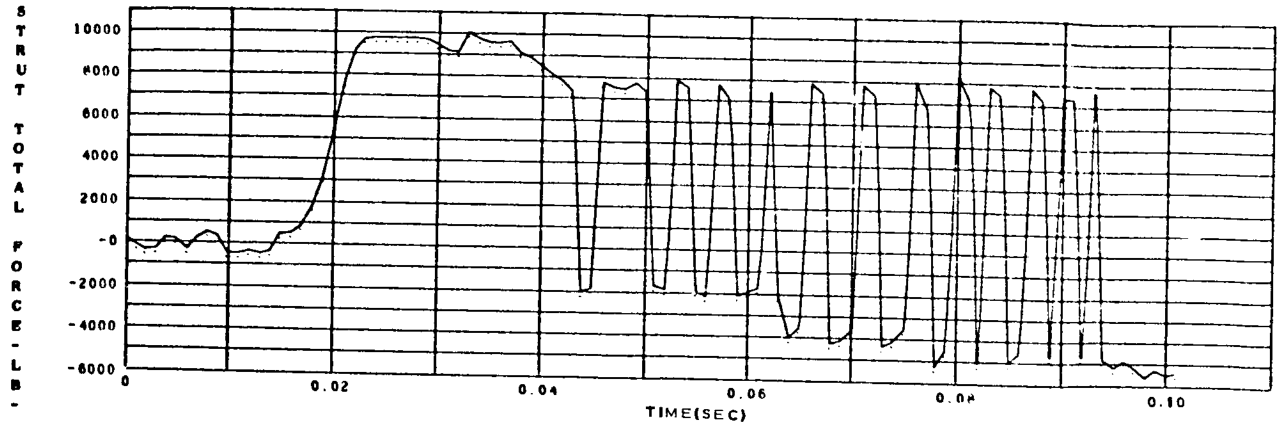


(b) Strut honeycomb force as a function of time.

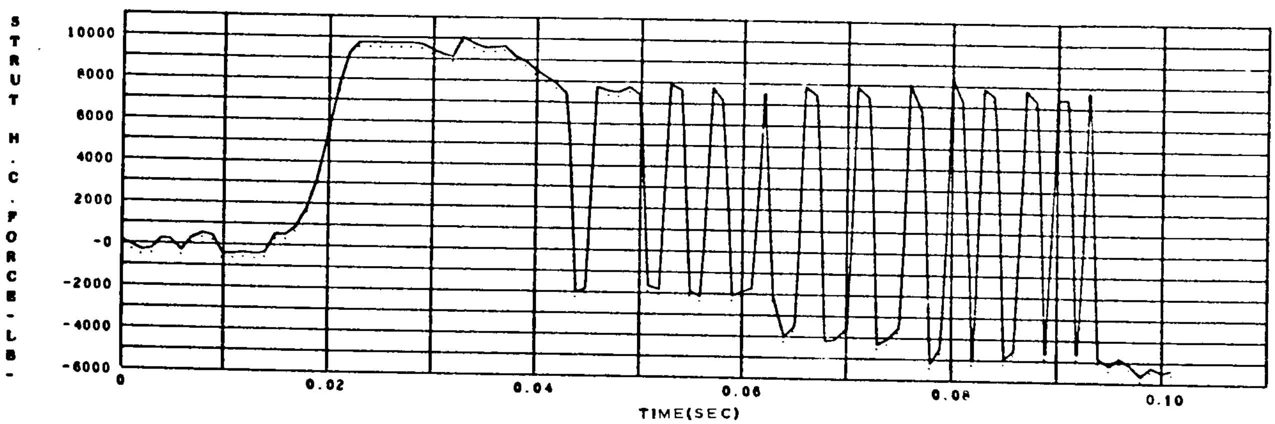


(c) Strut stroke as a function of time.

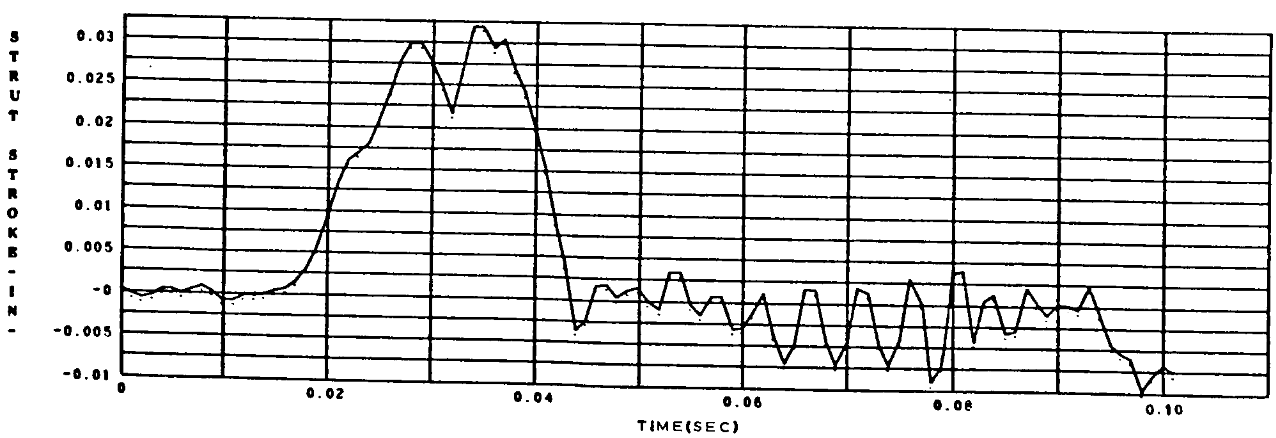
Figure B-6. - Strut 3 microfilm-recorder graphs from the sample run.



(a) Strut total force as a function of time.

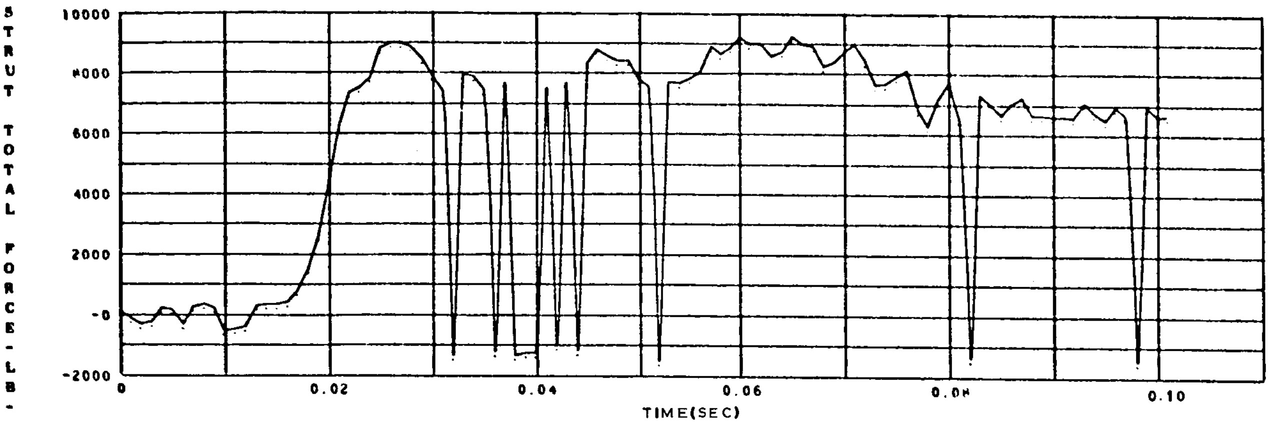


(b) Strut honeycomb force as a function of time.

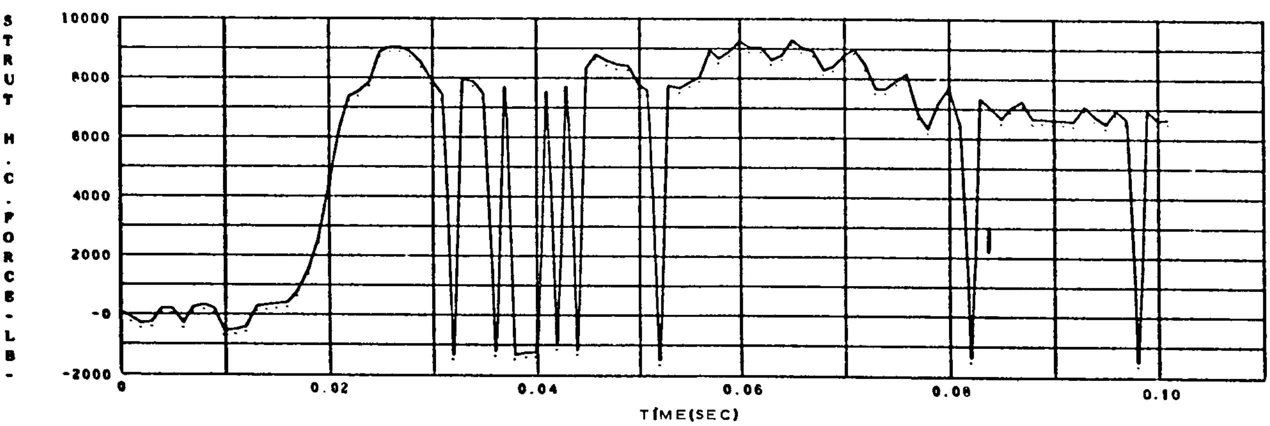


(c) Strut stroke as a function of time.

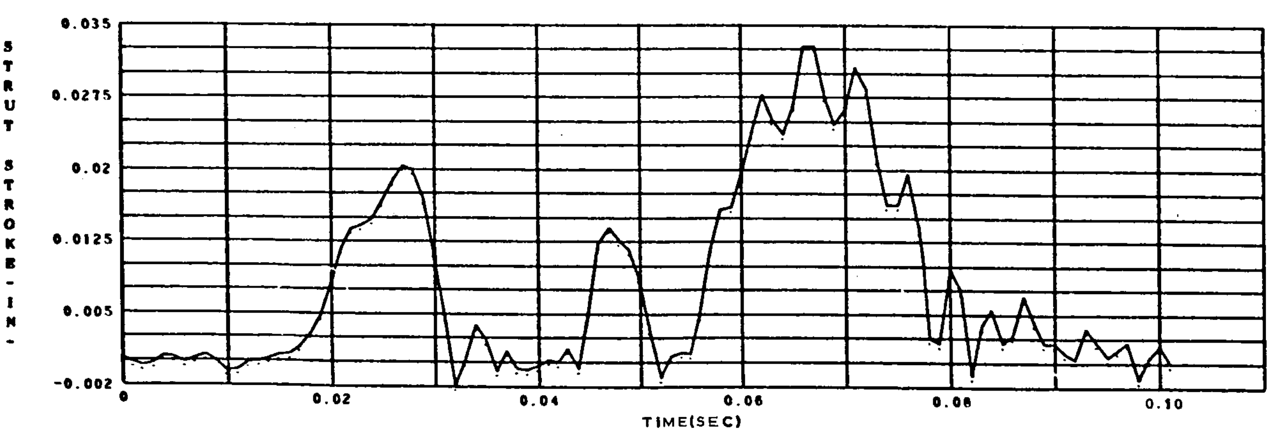
Figure B-7. - Strut 4 microfilm-recorder graphs from the sample run.



(a) Strut total force as a function of time.

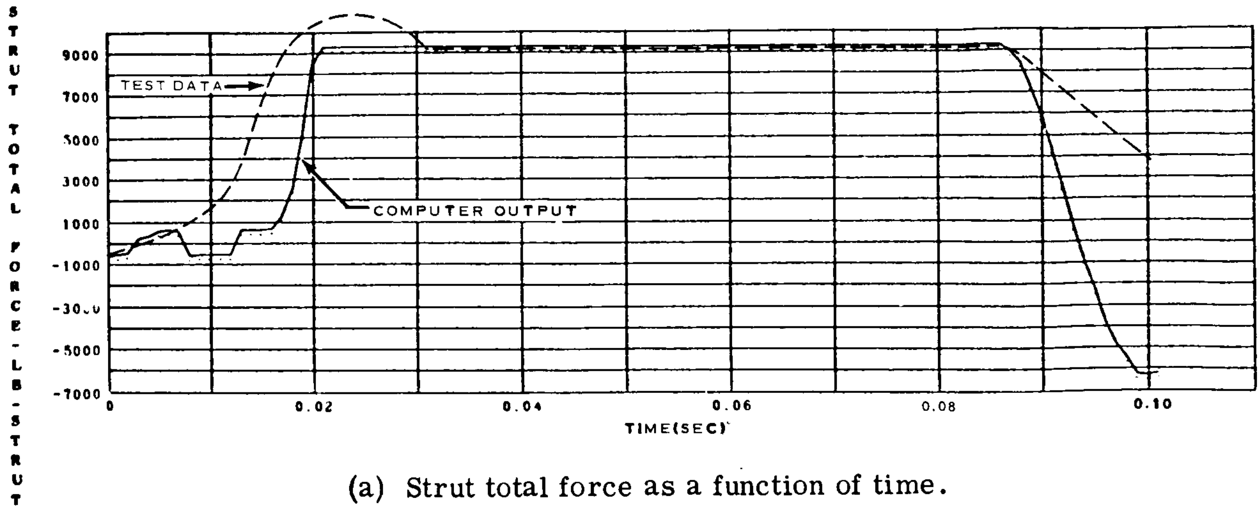


(b) Strut honeycomb force as a function of time.

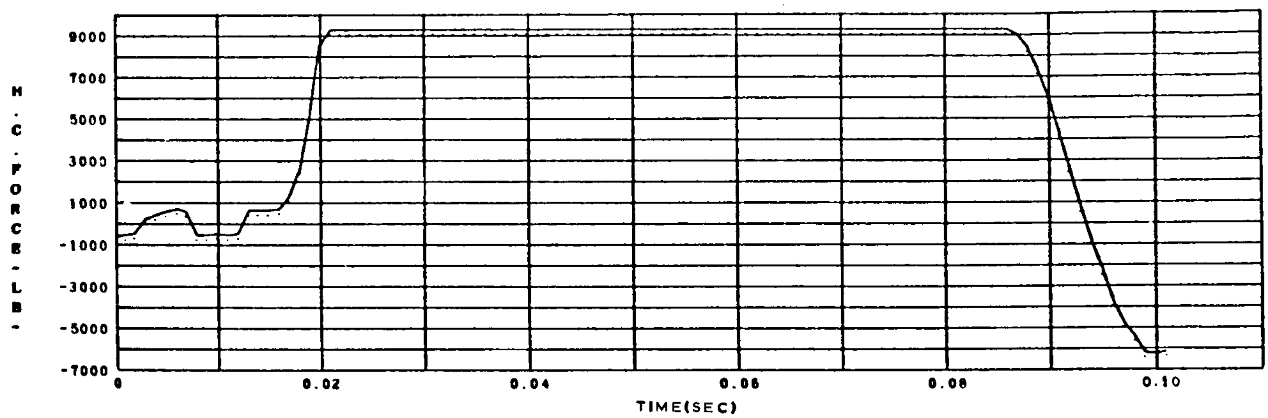


(c) Strut stroke as a function of time.

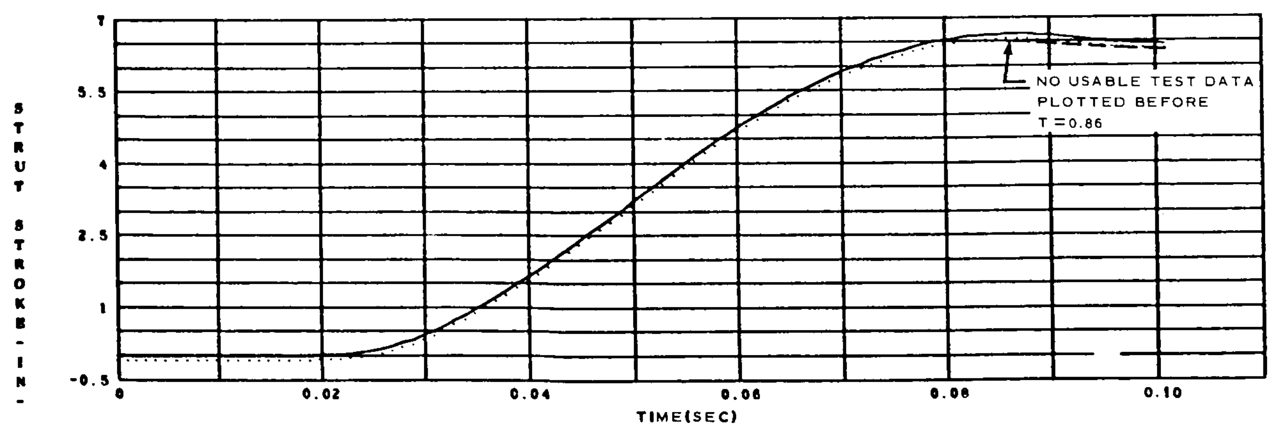
Figure B-8. - Strut 5 microfilm-recorder graphs from the sample run.



(a) Strut total force as a function of time.

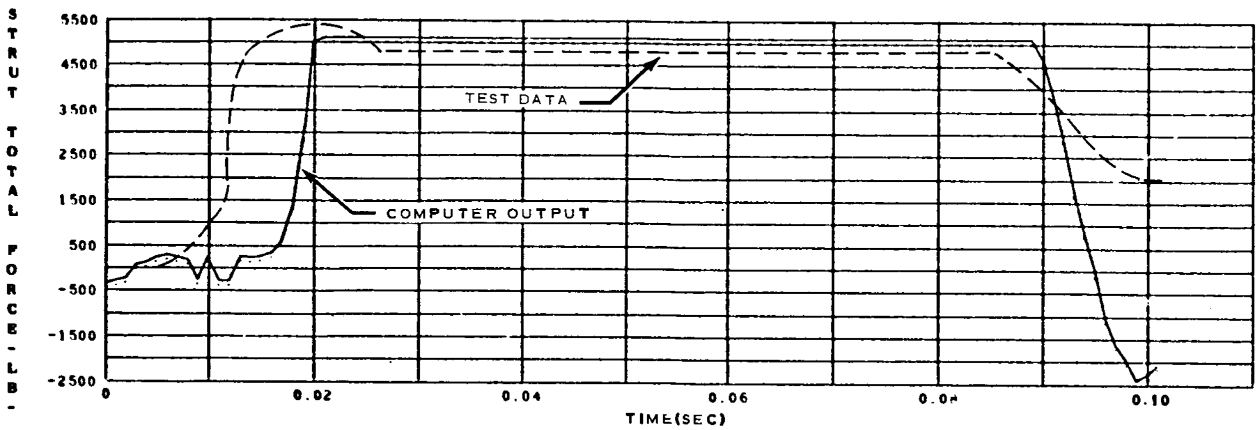


(b) Strut honeycomb force as a function of time.

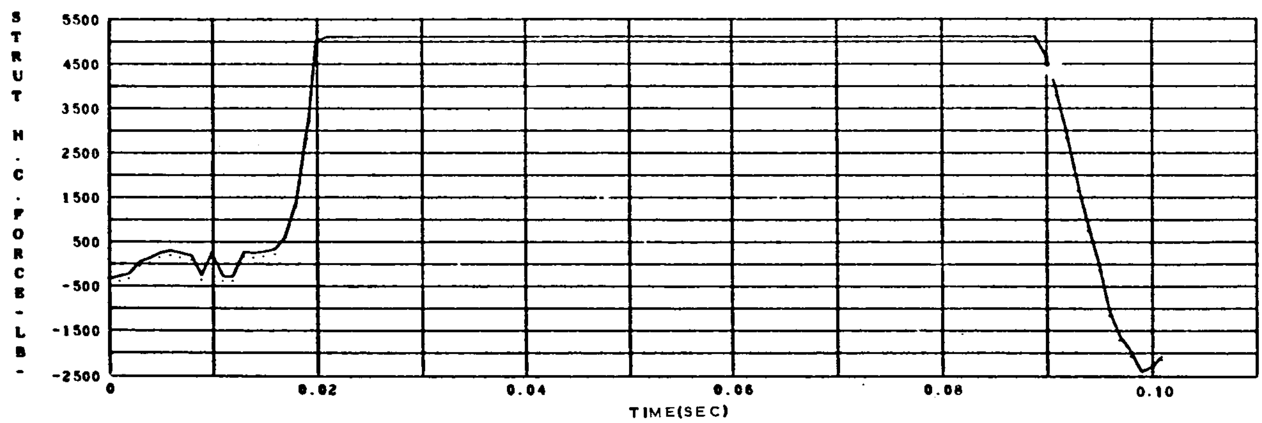


(c) Strut stroke as a function of time.

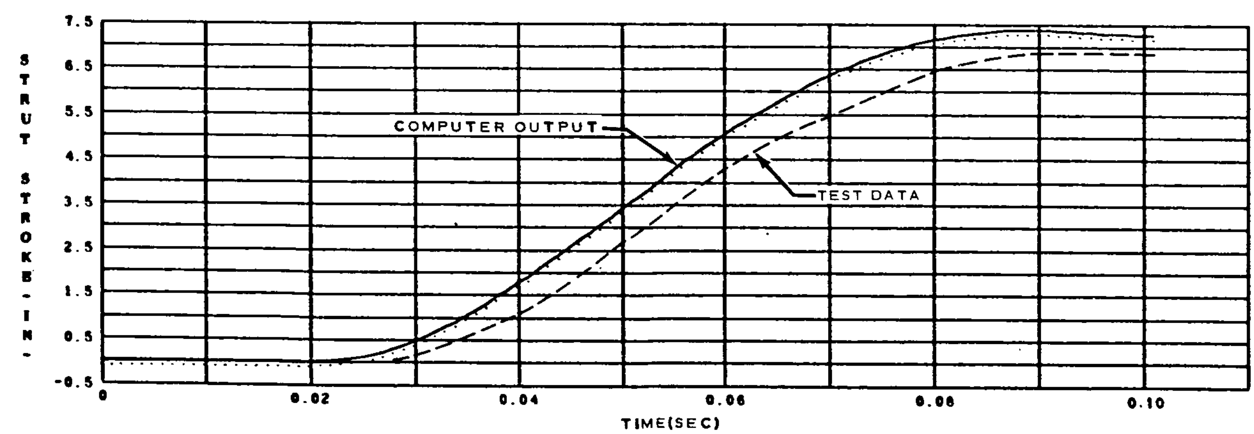
Figure B-9. - Strut 6 microfilm-recorder graphs from the sample run.



(a) Strut total force as a function of time.

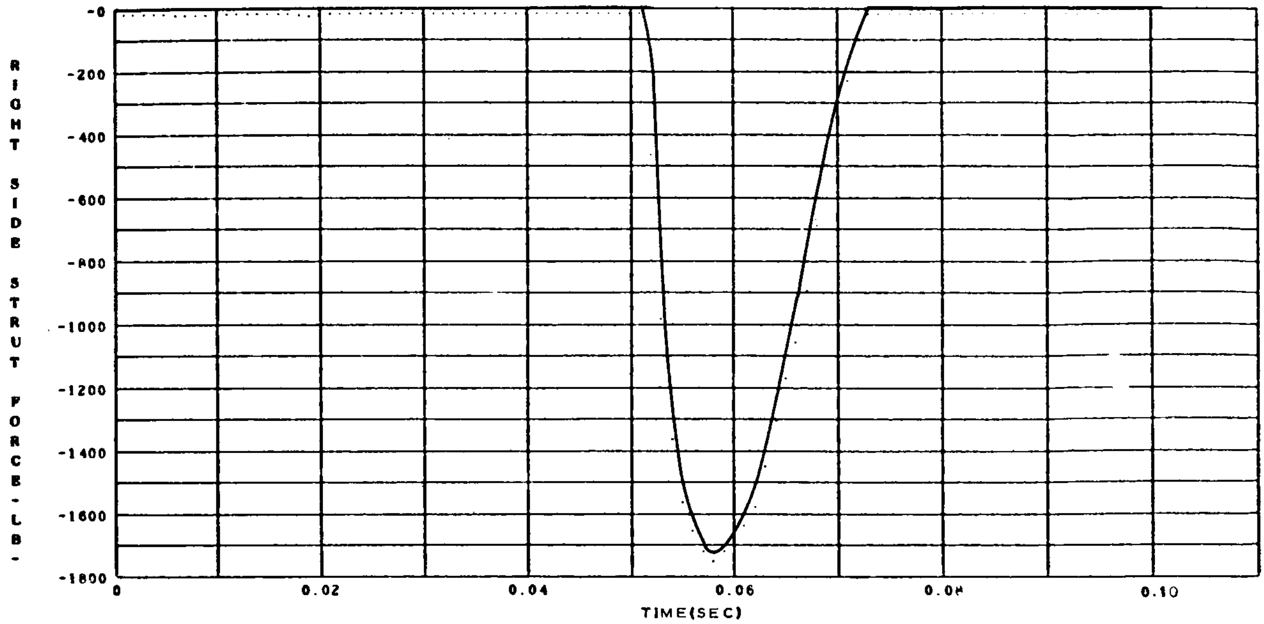


(b) Strut honeycomb force as a function of time.

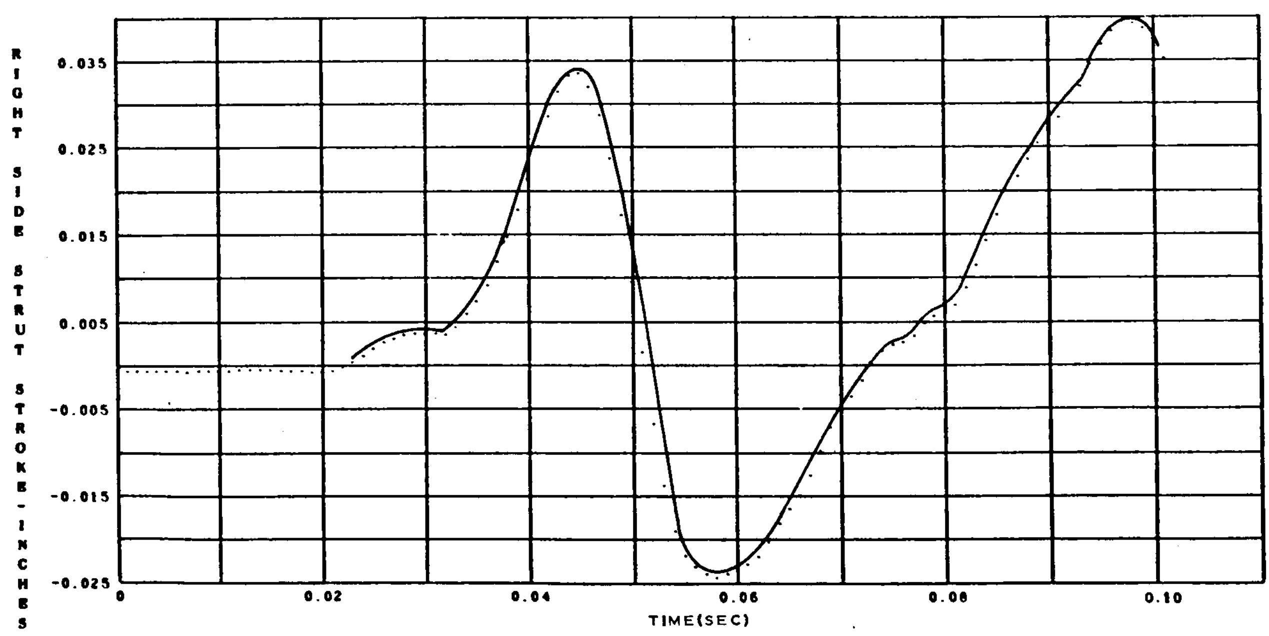


(c) Strut stroke as a function of time.

Figure B-10. - Strut 7 microfilm-recorder graphs from the sample run.

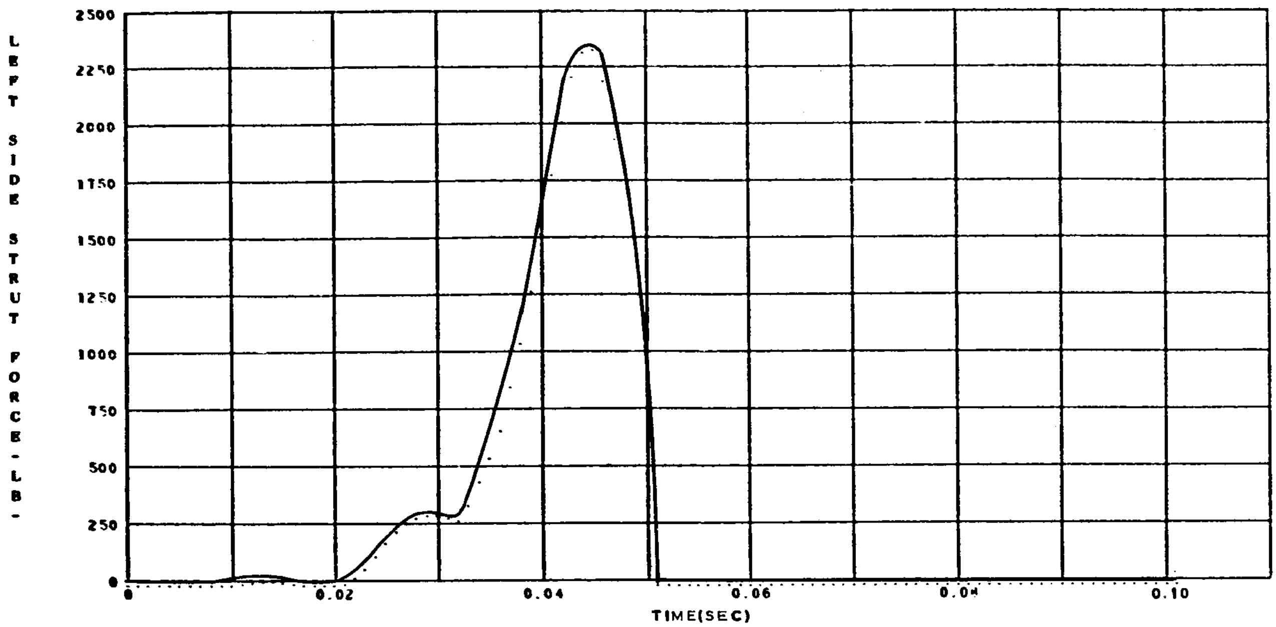


(a) Right-side strut force as a function of time.

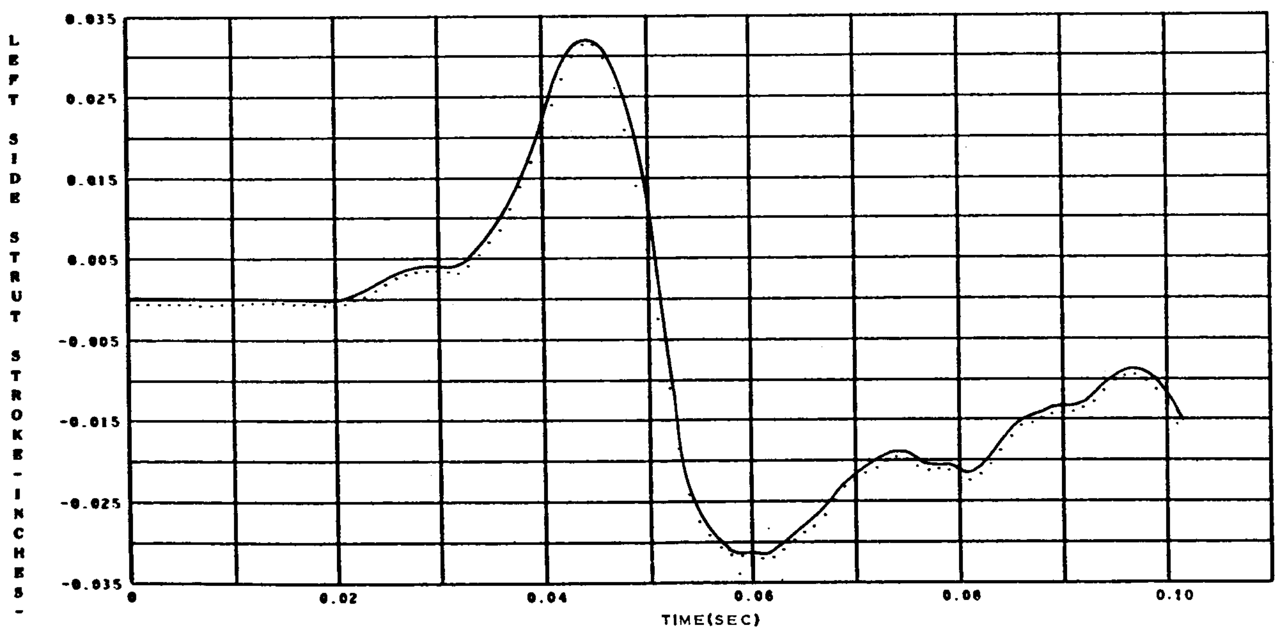


(b) Right-side strut stroke as a function of time.

Figure B-11. - Right-side microfilm-recorder graphs from the sample run.

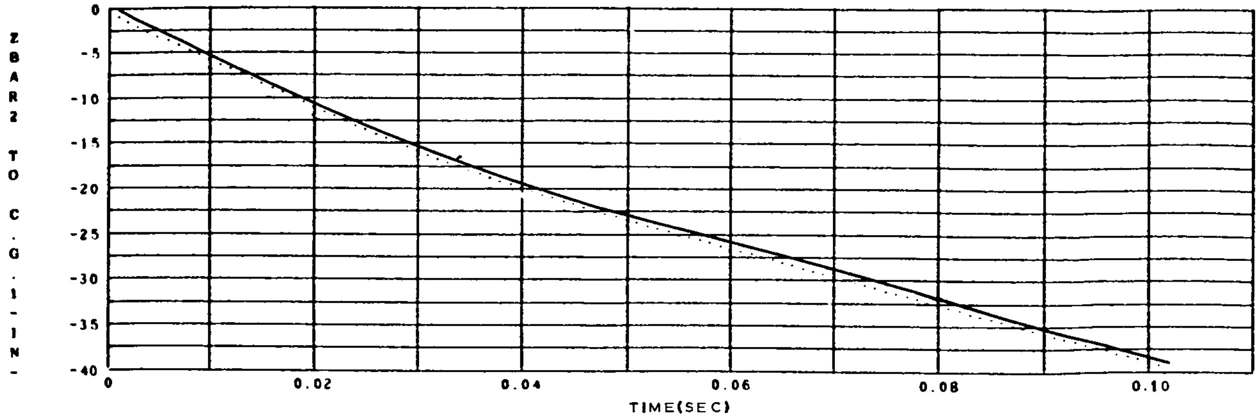


(a) Left-side strut force as a function of time.

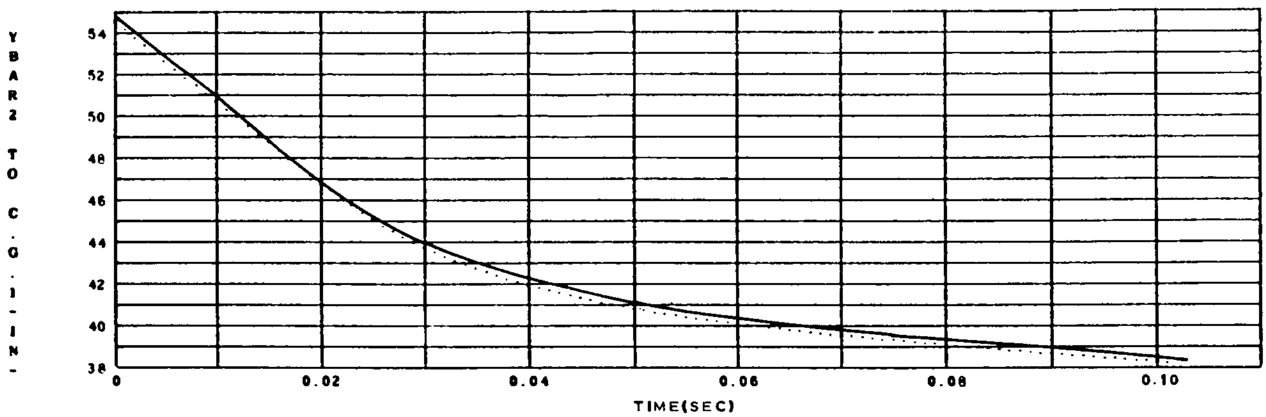


(b) Left-side strut stroke as a function of time.

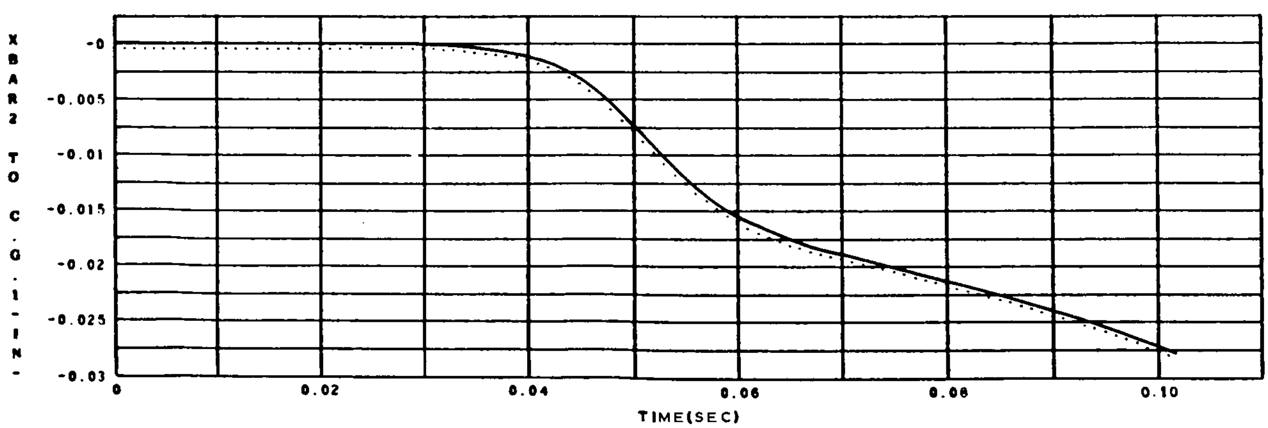
Figure B-12. - Left-side microfilm-recorder graphs from the sample run.



(a) Distance XBAR2 ($\bar{\bar{X}}_1$) to c.g.$_1$ as a function of time.

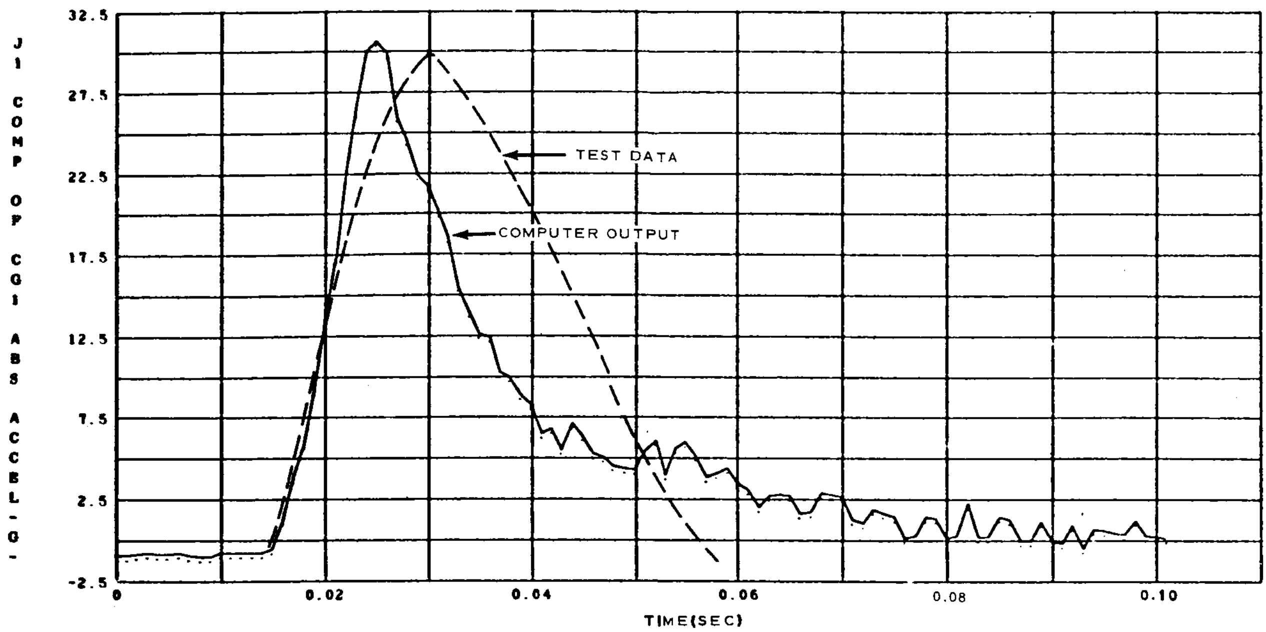


(b) Distance YBAR2 ($\bar{\bar{Y}}_1$) to c.g.$_1$ as a function of time.

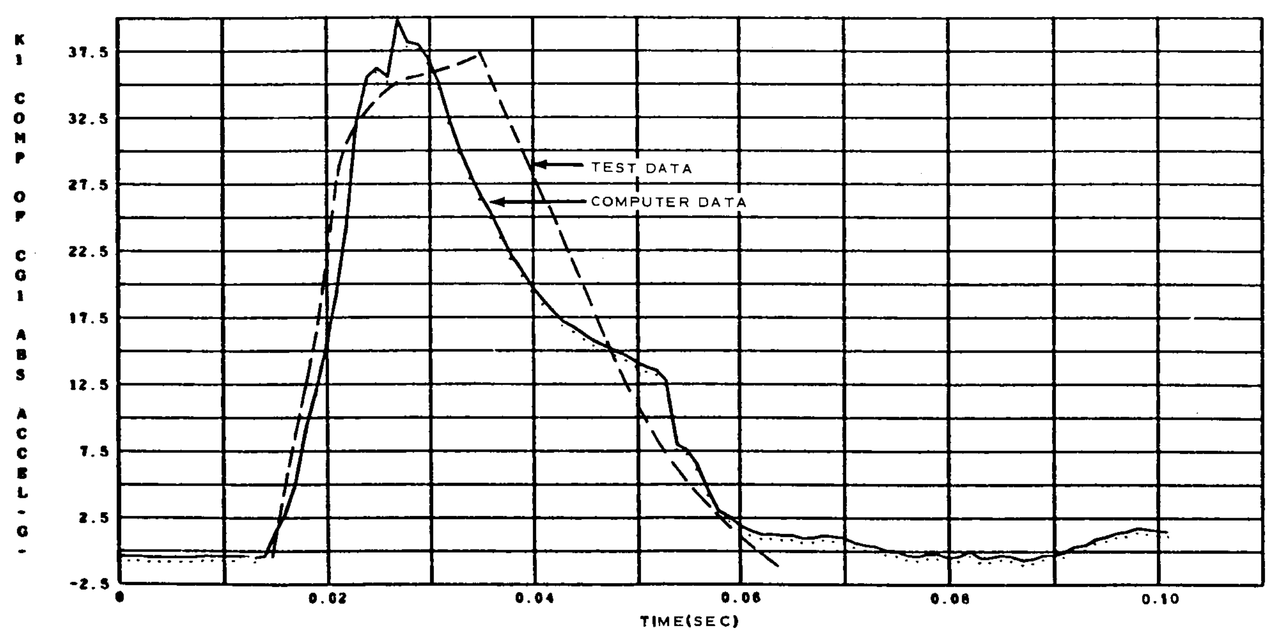


(c) Distance ZBAR2 ($\bar{\bar{Z}}_1$) to c.g.$_1$ as a function of time.

Figure B-13. - Distances XBAR2, YBAR2, and ZBAR2 to c.g.$_1$ as functions of time.

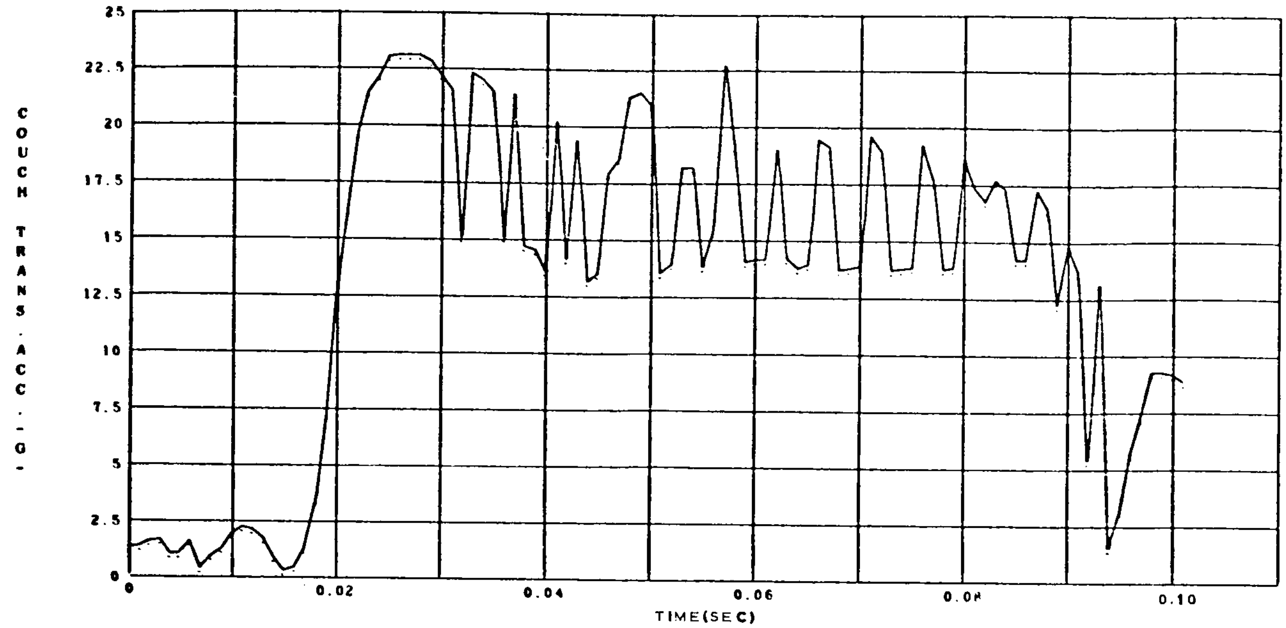


(a) The j_1 component of the absolute acceleration of $c.g._1$.

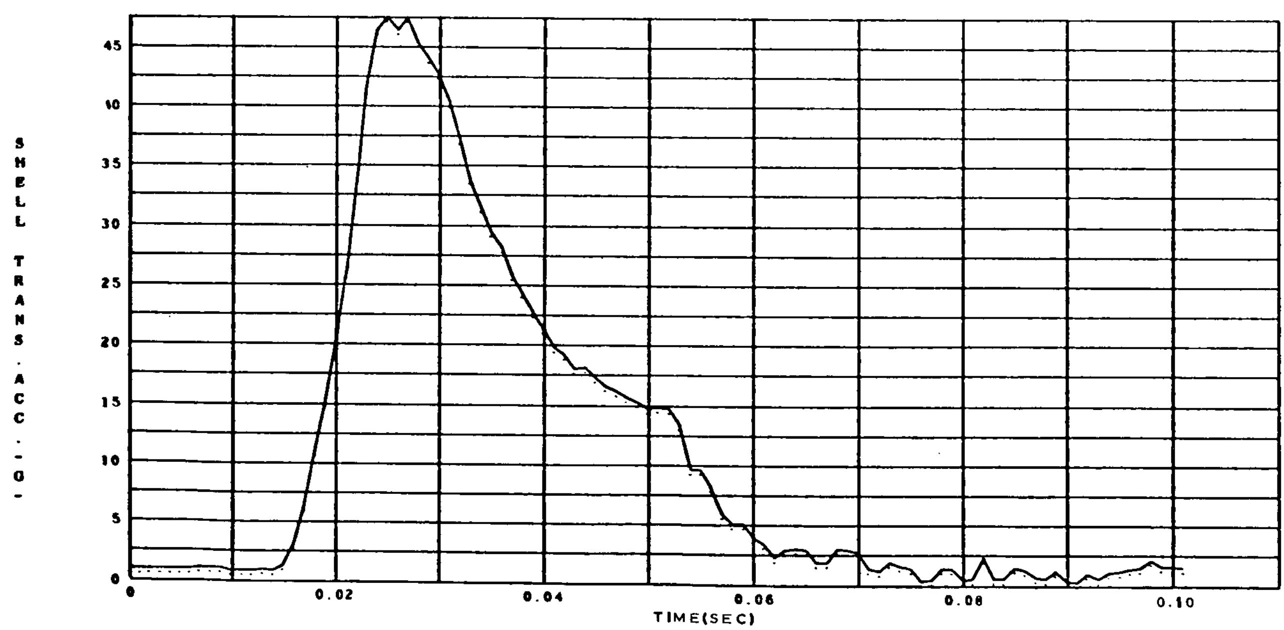


(b) The k_1 component of the absolute acceleration of $c.g._1$.

Figure B-14.- Microfilm-recorder graphs of the absolute acceleration of $c.g._1$ during the sample run.

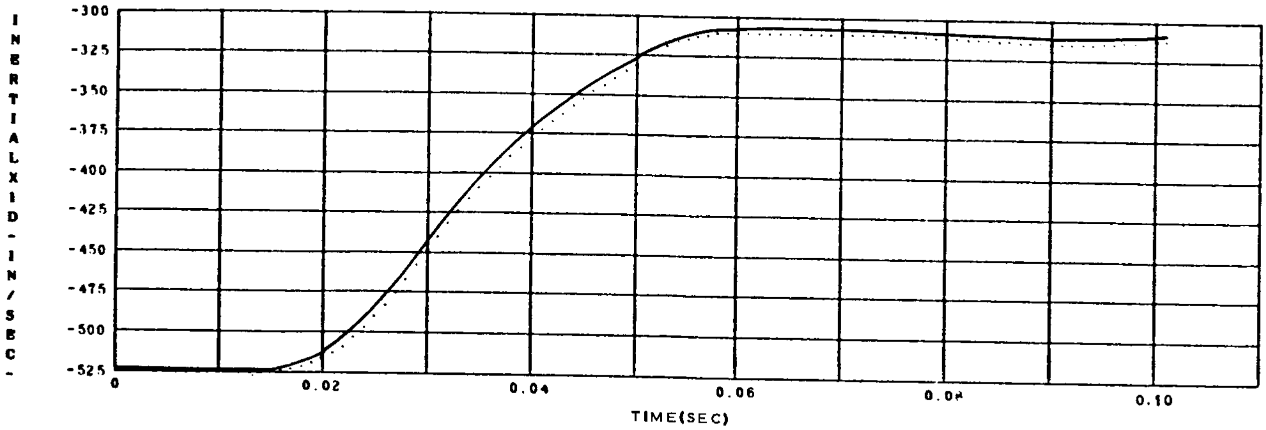


(a) Couch translational acceleration as a function of time.

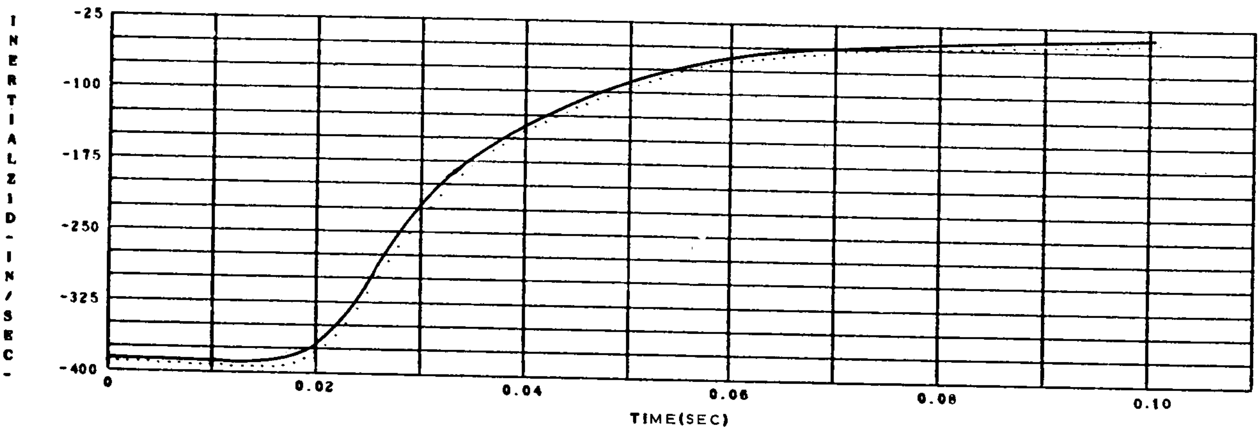


(b) Shell translational acceleration as a function of time.

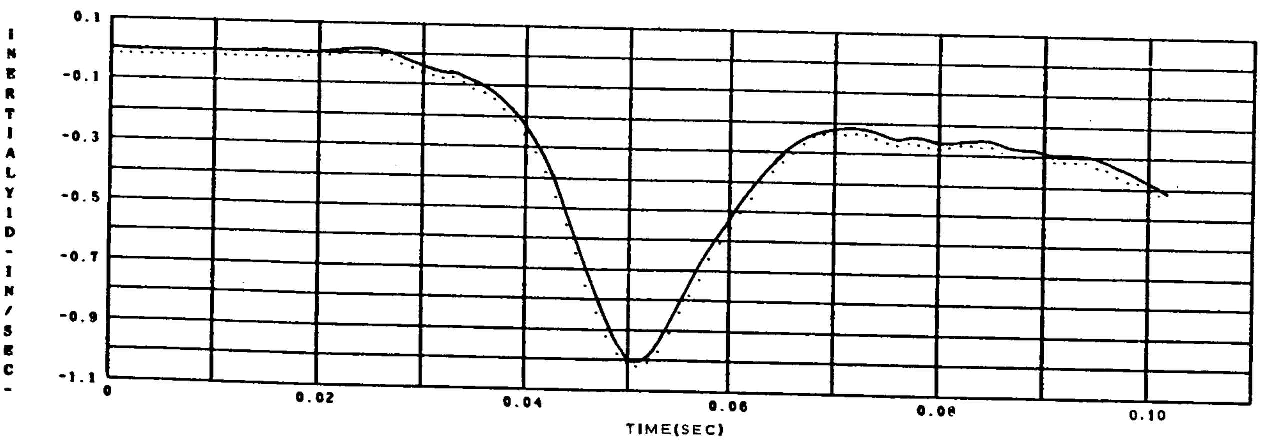
Figure B-15. - Microfilm-recorder graphs of the translational acceleration during the sample run.



(a) Inertial X1D ($\dot{\bar{\bar{\bar{X}}}}_1$) as a function of time.

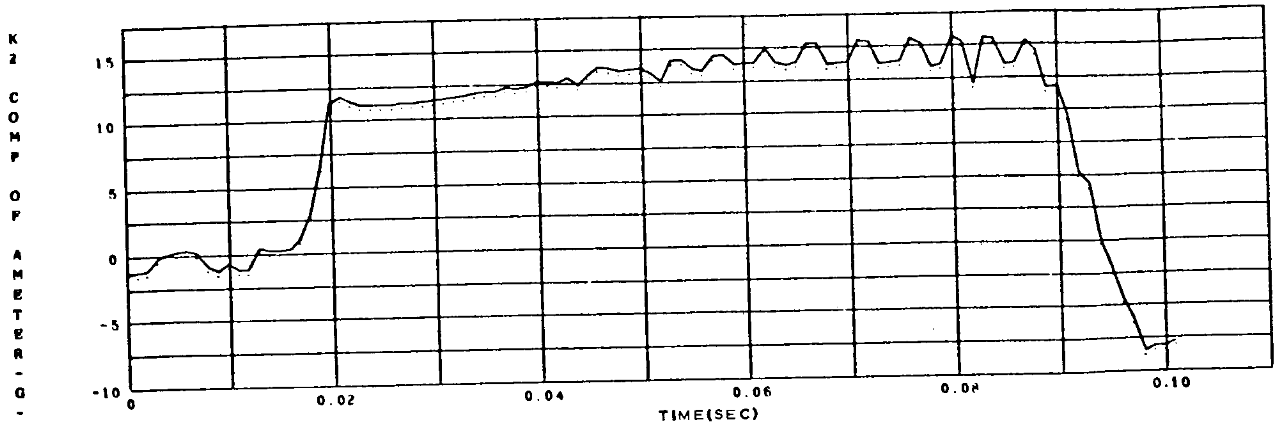


(b) Inertial Y1D ($\dot{\bar{\bar{\bar{Y}}}}_1$) as a function of time.

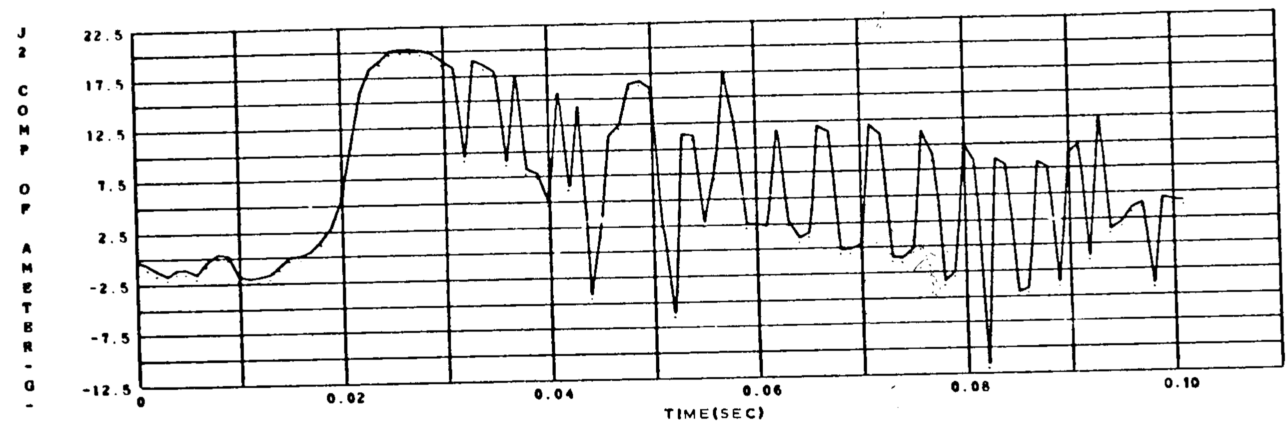


(c) Inertial Z1D ($\dot{\bar{\bar{\bar{Z}}}}_1$) as a function of time.

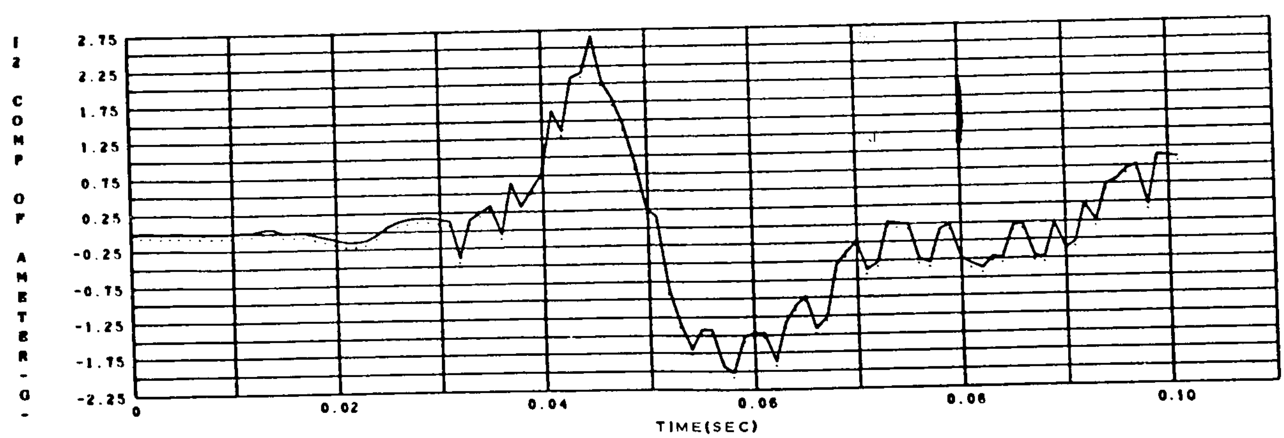
Figure B-16. - Inertial X1D, Y1D, and Z1D as functions of time during the sample run.



(a) The i_2 component of acceleration as a function of time.

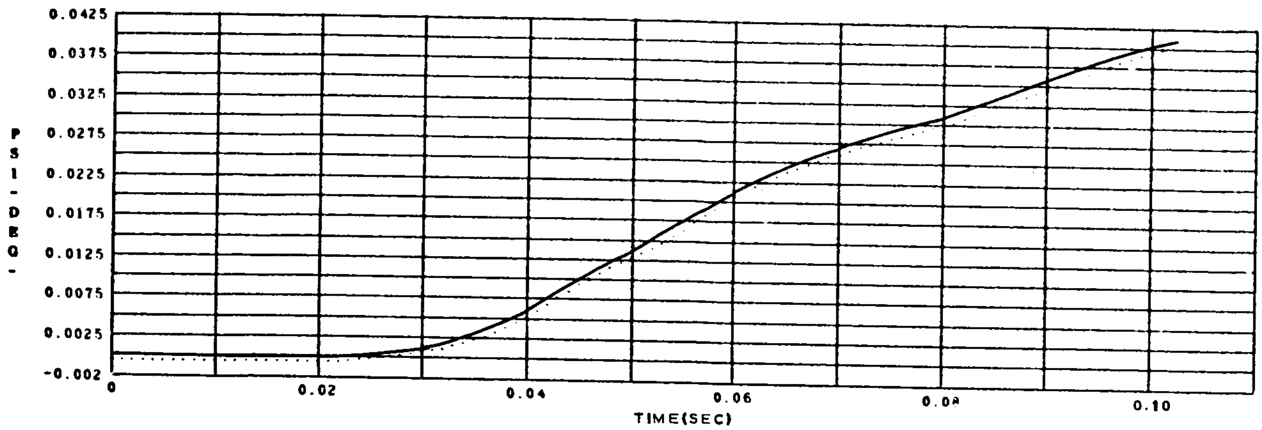


(b) The j_2 component of acceleration as a function of time.

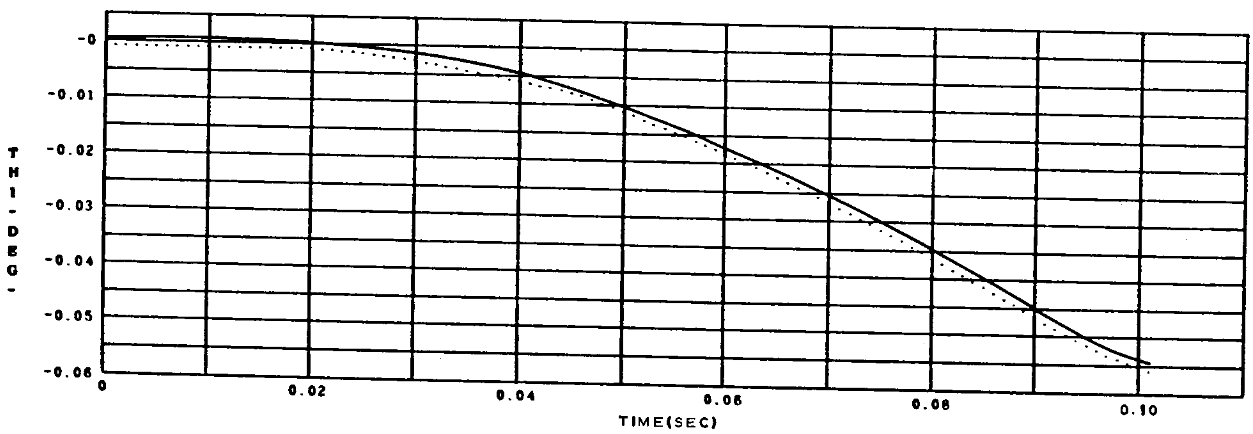


(c) The k_2 component of acceleration as a function of time.

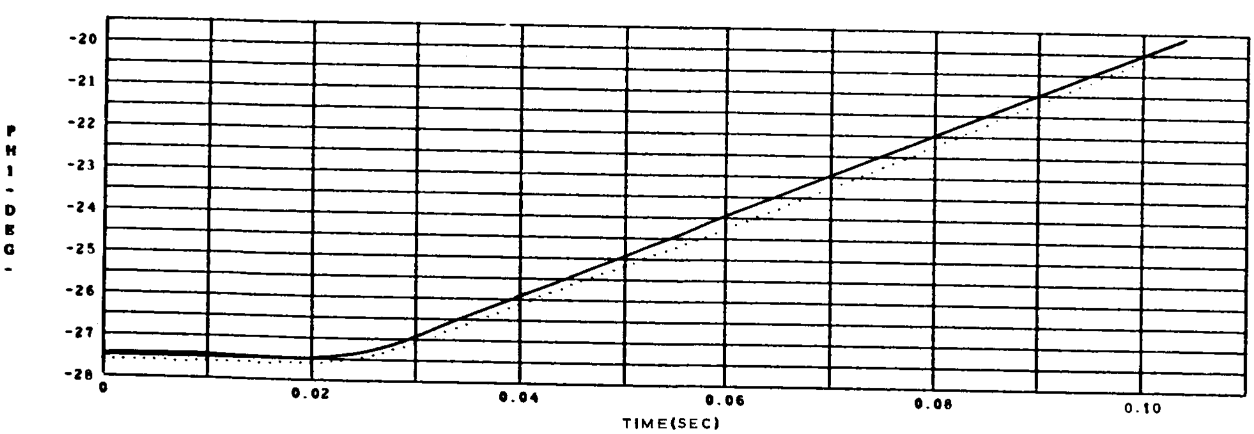
Figure B-17. - Crew-couch acceleration as a function of time during the sample run.



(a) Angle ψ as a function of time.



(b) Angle θ as a function of time.



(c) Angle ϕ as a function of time.

Figure B-18. - Microfilm-recorder graphs of ψ, θ, and ϕ during the sample run.

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ERRATA

NASA Technical Note D-6539

A FORTRAN V PROGRAM FOR PREDICTING THE DYNAMIC RESPONSE OF THE APOLLO COMMAND MODULE TO EARTH IMPACT

By William E. Thomas, Jr.
October 1971

Page 8: In the description of symbol LBC, change the word "length" to read "identifying number."

Page 13: (1) In the description of symbols $\bar{\bar{X}}$, $\bar{\bar{Y}}$, $\bar{\bar{Z}}$, change the axis designations X, Y, Z to $\bar{\bar{X}}$, $\bar{\bar{Y}}$, $\bar{\bar{Z}}$. (2) In the description of symbols $Y_{p,1+L}$, $Z_{p,1+L}$, change the symbol $c.g._2$ to $c.g._1$.

Page 16: In equation (1), change element 31 from $\sin\phi \sin\phi + \cos\phi \sin\theta \cos\psi$ to $\sin\psi \sin\phi + \cos\phi \sin\theta \cos\psi$.

Page 22: The beginning of the fifth line should read "... the strut relative to the other."

Page 25: The last five words in line 6 should read "... considered to be simply supported ...."

Page 26: Replace the word "friction" with the word "horizontal" in the first line following equation (53).

Page 27: (1) In the third line of paragraph 3, the phrase "... loading the edge-ring data." should read "... computing edge-ring loads." (2) The last five words in line 17 of paragraph 3 should read "Given the value at x ...."

Page 31: The symbols $\bar{X}_1$ and $\bar{Y}_1$ should be X_1 and Y_1.

Page 80: (1) The last line of the second paragraph should read "... FORMAT (9I5)." (2) The second item in the "Card code" column should read "Integer value" with corresponding "Input" description "Number of floating-point values to be input on cards." (3) An additional item should be inserted between "Integer value" and "Integer ≤ 19" in the "Card code" column as follows: insert the number "6" in the "Card code" column. The corresponding "Input" description should read "Number of auxiliary differential equations (control equations, etc.) to be integrated in the Runge-Kutta subroutine. This number is now 6 and may not exceed 18."

Page 82: Change "Remarks" for "Identification numbers" 110, 111, and 112 to read "Temporary values at input time only. (A card for each variable must be included each time a stacked run is made, even for zero values.)"

Page 90: The bracketed "Remark" does not apply to "Identification numbers" 7666, 7667, and 7668.

Page 91: The first two sentences in the third paragraph should be inserted in the seventh line of the first paragraph, so as to precede the sentence that begins "The integers used . . . ."

Page 92: Eliminate the sentence that begins "All other data . . ." from line 5 in the paragraph headed "SAMPLE PROBLEM."

Page 136: The bolt circle is labeled incorrectly; it should be the circle generated by r_6.

Page 146: The legends for graphs (a) and (c) should be exchanged.

Page 149: The legends for graphs (b) and (c) should be exchanged.

Page 150: The legends for graphs (a) and (c) should be exchanged.

Issued October 1972

NASA-Langley,